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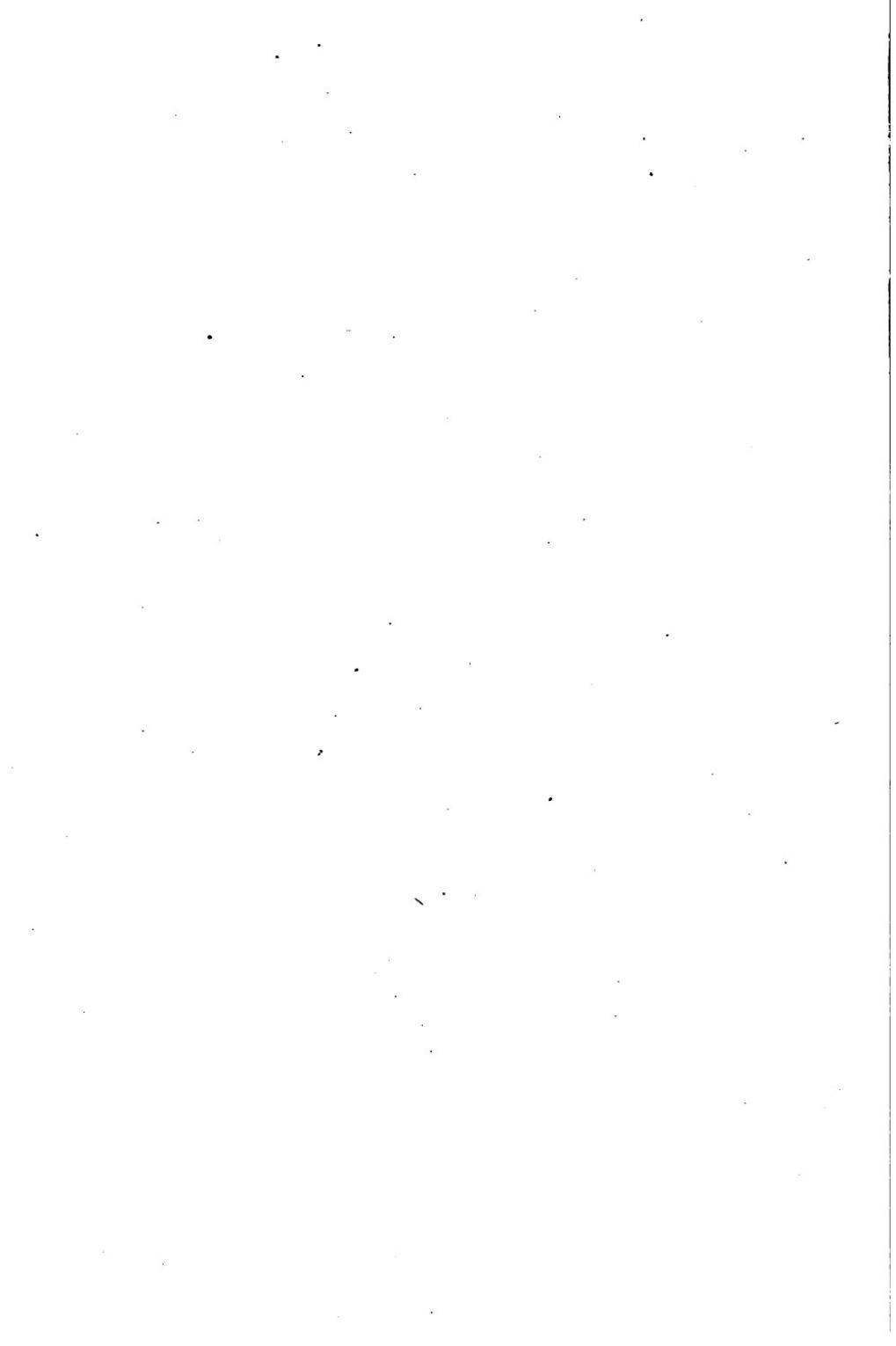


Albert W. Smith.

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Jan. '86.

A.Y.







MANUAL
OF
INTRODUCTORY
CHEMICAL PRACTICE

FOR THE USE OF STUDENTS IN

Colleges and Normal and High Schools

BY
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AND
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IN
CORNELL UNIVERSITY

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PREFACE.

This work is the result of a preliminary trial made with a class in the chemical laboratory of Cornell University, in the Fall Term of 1874. A small part of the matter contained in it was printed then in detached sheets for the use of the students. The work will be found on examination to present a mode of chemical practice which has the merit at least of novelty; and the experience of the authors justifies their expectation that it will be found to possess the more important merit of efficiency.

Its purpose and methods are fully explained in § I of the Introduction.

July, 1875.

PREFACE TO THE SECOND EDITION.

The authors in preparing the Second Edition of this manual, after its constant use in their laboratory for two years, have been guided by their experience especially with respect to the average capacity of the student for chemical work, and the value of an experiment in his hands for the illustration of a principle. A few experiments have been modified or rejected and others have been introduced, and another section has been added to the Introduction, which will, it is believed, render the Manual more useful for teachers who find the full course of experimental work already too long for the time at their command.

While the Manual is an introductory work, designed originally for the use of students entering upon an extended course of chemical practice, it may be used with profit, as it has been by the authors, for the instruction of students who have too little time at their disposal for a subsequent course of practice in chemical analysis.

July, 1878.



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INTRODUCTION.

§ I.

It is the two-fold purpose of this book to provide a course of laboratory practice in chemistry that shall serve to give the beginner in the study of the science a more familiar acquaintance with some of its important fundamental principles, than can be obtained from the study of text books alone, and at the same time to cultivate his powers of observation.

For the accomplishment of the first object, after the statement of a principle a series of experiments is given, which the student is expected to perform in illustration of it. For the better accomplishment of the second object, while the method of performing each experiment is carefully described, the result is not noticed at all; it is left for the student to observe and describe that and to trace its connection with the principle which the experiment is intended to illustrate.

Still a third end is accomplished, by requiring the student to give his results and conclusions in writing; precision and conciseness of statement may thus be cultivated; and a critical examination of his reports, by the teacher, may serve to help the student to discriminate between the essential and non-essential features of a series of phenomena resulting from an experiment, as well as to inform him whether his observations and conclusions are correct.

For beginners in chemical laboratory practice the experiments should not be difficult of execution, nor should they involve the use of expensive apparatus; and the results should be unequivocal.

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cal, if the experiments are performed with reasonable care. Therefore all difficult or dangerous experiments have been omitted, and almost every experiment given has been tested, to make sure that it will lead the student to the expected result, if not the first time, certainly on being repeated with more care.

As the beginner in chemical laboratory practice is, in general, entirely ignorant of the names and uses of the various pieces of chemical apparatus that are put into his hands, this apparatus is figured in the following section; the whole section is intended to serve as a glossary, to which the student may turn whenever he desires to ascertain the meaning of a technical term, whether it be the name of a piece of apparatus, or of some mode of manipulation, or if he wishes to learn how to use any piece of apparatus in a proper manner.

As the student is no less ignorant in regard to the quantities of material required for the successful performance of an experiment, the quantities are prescribed in the description of each experiment.

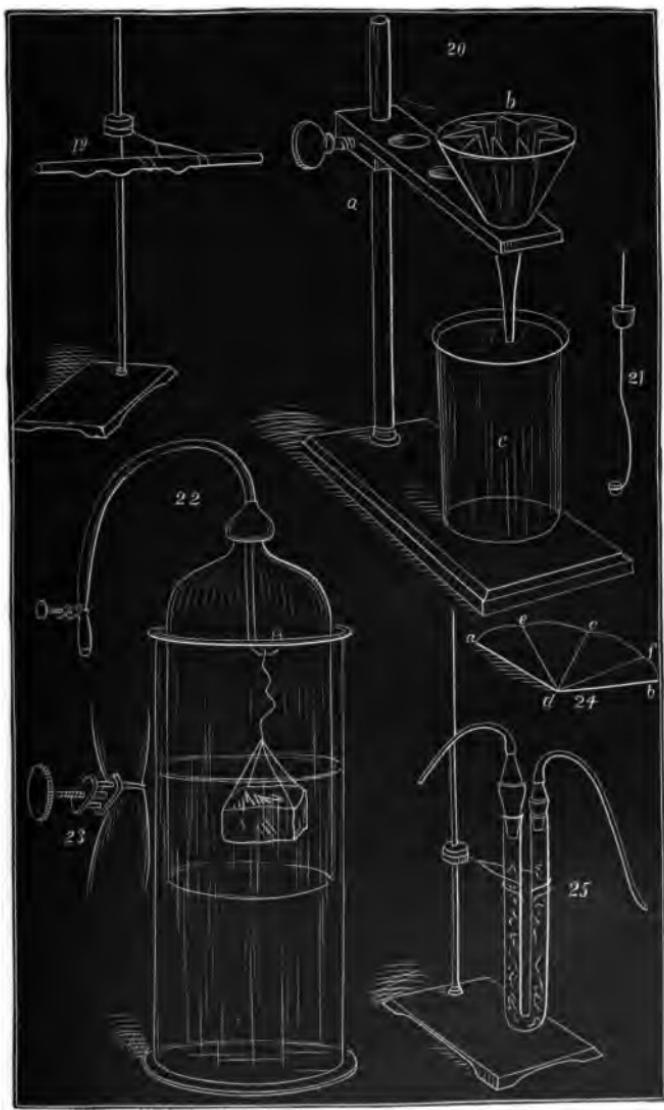
It being presumed that the student taking this course of practice will at the same time be attending a course of lectures or recitations on chemistry, matters pertaining to chemical theory are, in the main, left to the teacher. In order, however, to help him to attain a better understanding of the reactions involved in the experiments that he is performing, as well as to give this work such a character that it may serve as an introduction to a course of practice in qualitative analysis, so much theoretical statement is given in chapter XIV as is required to enable the student to make correct and intelligent use of *equations* in explaining chemical reactions.

For the benefit of the teacher, who has to provide the means for carrying on the work of the laboratory, a complete account is given in § II not only of the apparatus to be issued to each student but of that required for general use; and in § III, a full list is given of the chemicals and other supplies needed.

With each copy of the book a separate slip will be sent out, specifying the amount of student's apparatus and of chemicals that it will be advisable to purchase for every ten students taking this course of practice.









§ II.

APPARATUS AND MANIPULATION.

Adapter.—Fig. 1 c. A tube of heavy glass 1.5 cm. in diameter at its widest part and 6 or 7 cm. long, *fig. 5*, over the larger end of which is fitted a piece of thick-walled rubber tubing, 3 cm. long. It can serve as a perforated rubber stopper, and, by slipping the tube up or down, can be made larger or smaller, and adapted to tubes of different sizes; or the free end of the rubber tube may be slipped over the end of a tube whose bore is too small to receive it. It is used to conduct away volatile products, generally in connection with the small exit tube to which it is attached by a piece of rubber tubing on its smaller end. The rubber tubing on the larger end should be removed and cleaned after having been used.

Balance.—A small one, such as the pharmaceutical balance in glass case, marked No. 1 in Becker's catalogue, carrying a weight of fifty-six gms., and sensitive to somewhat more than one mgm., will answer for the quantitative work. It should not be kept in a room where there are any acid fumes. Concerning its use, see *Weighing*.

Ball Valve.—Fig. 13. This is a most ingenious device for controlling the flow of liquids or gases in rubber tubes. A ball of glass, or a very short glass rod with rounded ends, somewhat larger than the bore of the rubber tube, is inserted in it; the flow of the gas or liquid is secured through a little channel made by pinching a fold of rubber at one side of the ball. The best rubber tubing free from furrows along the inside wall is required for this valve.

Battery, galvanic.—Four Lockwood cells, or their equivalent in some other form, will answer.

Beakers.—Fig. 20 c. Glass vessels with thin bottoms; a nest of the three smaller sizes, ranging from 7 to 10 cm. in depth is required in the quantitative work, Chap. XXI.

Blue glass.—A piece of dark blue, cobalt window glass, 6 by 10 cm., and at least 2 mms. thick.

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Bottles.—All reagents should be kept in well stoppered bottles, those containing liquids having glass stoppers. These may be of 200 to 250 c.c. (6 to 8 oz.) capacity for acids, ammonium and sodium hydrates, and of smaller size for the other reagents kept by the student. Dry reagents should be kept in small, 30 to 60 c.c. (1 to 2 oz.) wide-mouthed bottles. Every bottle should be plainly labeled with the name and symbol or formula of the substance contained in it.

Bottle gasometer.—Fig 6. This instrument is used for manipulating and roughly measuring gases. The bottles should be square shouldered with flat bottoms, and of $\frac{1}{4}$ to $\frac{3}{4}$ litre (4 to 8 oz.) capacity. They should be firmly bound together with stout cord and kept from actual contact by thin pieces of cork between them. The doubly perforated corks closing their mouths and carrying the bent tubes are sunk below the lips of the bottles and covered with cement or sealing wax; the bottles are connected with each other and with the tubes *c* and *d* by short pieces of soft rubber tubing, the piece on *d* containing a ball valve. The measuring bottle *a* is graduated by fastening upon its side a slip of writing paper divided with a pen into five equal parts; the paper is afterwards covered with varnish to protect it from moisture. To use the apparatus for measuring gases, dip the mouth of the exit tube *d* in water, open the valve and draw air through the mouth tube *c* till both bottles are half full of water, then blow into the same tube until all the water is expelled from *a*, and *b* is entirely full, and, finally, close the valve. Attach the tube *d* to the generator or reservoir of gas to be used, open the valve and measure the volume of gas entering the gas bottle *b*, by reading on the scale the equal volume of water which it forces into the measuring bottle *a*, closing the valve immediately when the desired quantity has entered. To force out the gas, blow through the mouth tube into *a*. Always fill *b* with water and *a* with air before proceeding to a new experiment; open the ball valve whenever any motion of gas or liquid is to be obtained within the apparatus, and, to avoid danger, never bring a flame near the apparatus while it contains combustible gases.

Bottle gasometer, large.—A large instrument similar in every other respect to the one just described, but made with bottles of

3 to 4 litres capacity, may be used as a reservoir of gas for the laboratory.

Bottles, pouring from.—In pouring a liquid from a bottle, hold the bottle in the right hand with the label towards the palm, remove the stopper with the third and fourth fingers of the left hand, and pour the liquid into the test tube held between the thumb and index finger of the same hand; then catch the drop adhering to the lip of the bottle by touching it with the stopper, replace the latter and put the bottle back in its place on the shelf. If these directions are followed, neither stopper nor bottle need be placed on the table, and the test tube being all the while exposed to view, any action taking place within it is plainly seen.

Bunsen burner.—See *Lamp*.

Bunsen cells.—See *Battery, galvanic*.

Charcoal splinters.—Splinters of pine wood, about 6 cm. long and 3 mm. thick, saturated with sodium carbonate by soaking in a strong solution of that salt and afterwards dried. When heated in the flame they yield a mixture of charcoal and sodium carbonate well suited for the reduction of a metal from its compounds. In using the splinter, one end is charred in the flame, slightly moistened, dipped into the pulverized substance and heated at the point of the inner blue cone of the flame.

Corks.—Soft, compact corks suited to the two sizes of test tubes will be required most frequently; the flat corks occasionally needed may be cut from the ends of these. Large corks are used for making test tube holders described under that heading. All corks should be softened by rolling between two hard surfaces before being fitted to glass vessels, and particularly in the case of test tubes the cork must be inserted with a spiral motion assisted by very moderate pressure.

Crucibles, porcelain.—Fig. 17. Three sizes are required, viz., No. 5, 6 and 8, about 4, 3.3 and 2.3 cm. respectively in depth. The first two sizes are required only in the quantitative work of the last chapter, while the third is used throughout the other portions of the book.

Decantation.—A liquid is sometimes decanted or poured off from a sediment when the latter is not easily disturbed; the

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longer process of filtration may thus be shortened or entirely dispensed with.

Deflagrating spoon.—Fig. 21. Made of copper or brass and used for testing the combustibility of solids in oxygen or some other gas. The bowl, 1.3 cm. in diameter is riveted to the wire, 15 or 20 cm. long, which serves as a handle.

Desiccator.—For general use in the laboratory, this may consist of a flat bell-jar about 20 cm. in diameter, resting on a ground glass plate on which is put a dish containing concentrated sulphuric acid. A tripod of copper wire or a tier of light shelves may be used to support the dishes or watch glasses containing the substances to be dried.

Digestion.—A term applied to the long continued action of a liquid on a substance, generally with the aid of a moderate heat.

Displacement.—See *Gases*.

Drying oven or drying bath.—One with the inner box 15 by 15 cm. will answer for a small class; if made of tin it is cheaper but less durable than one made of copper.

Drying battery.—A collection of drying tubes held together by rubber bands. See *Drying tubes*.

Drying tubes.—Fig. 25. U shaped tubes 1.5 cm. in diameter with limbs 15 to 20 cm. long, and nearly filled with fragments of pumice stone saturated with concentrated sulphuric acid. They may be conveniently connected by adapters with the tubes conveying the gases to be dried by passage through them. They should be tightly closed with corks when not in use.

Evaporators.—Fig. 18. Dishes of porcelain, used for heating liquids but not for heating dry substances. Two sizes will be required, one about 7, the other about 9 cm. in diameter.

Exit tube.—Fig. 1 e. A tube 30 cm. long and 4 to 5 mm. in diameter, used in connection with the adapter and also with the bottle gasometer.

File.—A small triangular file for cutting glass tubes.

Filters.—To prepare a filter for use, fold it twice along diameters at right angles to each other, open the quadrant thus formed in such a manner as to make a hollow cone, put it into a glass

funnel somewhat deeper than the filter, moisten the latter with a little water from the washing bottle and gently press it with the fingers so that it shall be in contact with the funnel throughout. The filter should never be filled with liquid within 6 mm. of the top, nor more than half filled with a precipitate after the liquid has passed through. Ribbed filters, by the use of which more rapid filtration is secured, are made as follows; first fold the filter as usual, then laying it half open on the table raise the edges *ad* and *bd*, fig. 24, and, laying them on *cd*, make two new creases, *ed* and *fd*; then take the filter up and fold each of the segments, *aed*, *edc*, etc., in the middle in such a way that the four new creases shall be opposite in direction to those first made, *ed*, *cd*, and *fd*. On opening the filter and putting it into the funnel it will be seen to stand out from the walls of the latter touching it only along the edges of the folds, as shown in fig. 20 *b*.

A stock of filters, both ribbed and common, folded in leisure moments, should be kept on hand ready for use:

Filter stand.—Fig. 20 *a*. A wooden stand for holding funnels while filtering into evaporators or beakers.

Filtrate.—The liquid that passes through the filter.

Filtration.—This term is applied to a process of separating a solid from a liquid with which it is mixed, by the use of porous, unsized paper which intercepts the solid, unless too finely divided, but allows the liquid, with all matters that it holds in solution, to pass through. Hot liquids, in general, filter more rapidly than cold, and crystalline precipitates are less liable to choke up the paper and impede filtration than gelatinous ones. In case the substance collected on the filter is to be used for further experiments, it must, in general, be washed with hot water till freed from the matters in solution in the liquid with which its pores were at first filled.

To transfer a substance, while still moist, from the filter to another vessel, spread the filter open on a clean glass plate and take the precipitate up on a spatula; or, if its admixture with water is not objectionable, a hole may be broken through the point of the filter with a clean glass rod, and the precipitate may be washed down through the neck of the funnel with the jet of the washing bottle.

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Filtration, quantitative.—In case a precipitate is to be collected on a filter and weighed, one of two methods may be followed; the filter and its contents may be ignited in a crucible and the weight of the filter ash deducted from the total weight of the residue; or the filter and its contents may be dried by long exposure to a temperature of 100° C., and weighed. To balance the filter itself in the latter case, the following mode of procedure is most convenient: trim off the heavier one of two filters, made of the same kind of paper, so that they will exactly balance one another; then collect the precipitate on one of these filters and pour the filtrate thus obtained through the other filter, and wash both filters in the usual manner; dry them at 100° C., in the drying oven, and, finally, put the filter with its precipitate on one pan of the balance and the empty filter on the other; the additional weight required to balance them gives at once the weight of the precipitate. Both filters being treated precisely alike, except that one receives the precipitate while the other does not, they will be affected in the same way in regard to loss of soluble matters from the paper, loss of water in drying, or gain in water absorbed from the air after removal from the drying oven. This method is more simple than the one first mentioned, and the results are sufficiently accurate for the present purpose.

Finger caps.—The rubber finger caps sold by druggists can be used to protect the thumb in shaking the contents of test tubes, or while otherwise handling corrosive liquids, such as acids, alkalies, silver nitrate, etc.

Flasks.—Fig. 12. None but thin bottom glass flasks should be used. These should be of several sizes, from 30 to 120 c.c. (1 to 4 oz.) capacity, some with round, others with flat bottoms.

Funnels.—Fig. 14. Sizes from 4 to 8 cm. in diameter will be most used. Those having an angle of 60° are best suited for filtration.

Gas bags.—Rubber bags of 8 to 40 litres (2 to 10 gallons) capacity are commonly used as reservoirs of gas. They should be placed between pressing boards, hinged together and loaded with weights to secure the desired pressure.

Gas, collection of by displacement.—Gases which differ considerably from air in weight may be collected without the use of the

pneumatic trough, by simply carrying the tube delivering the gas to the bottom of the vessel in which it is to be collected; in the case of gases lighter than air, such as hydrogen, the vessel must of course be inverted to prevent its escape from the mouth. This method is called *collection by displacement, upward or downward*, as the gas is lighter or heavier than the air.

Gas, collection of, over water.—To fill a test tube or jar with gas, the vessel is first filled with water, and, after being tightly closed with the hand or a small glass plate, is put mouth downward in the pneumatic trough, with care that no air be allowed to enter; the delivery tube of the gas generator or reservoir is then brought into the water, and, after a few bubbles of air have been allowed to escape from it, it is introduced into the mouth of the inverted vessel; as the gas enters the liquid descends, and when bubbles of gas escape from the mouth of the vessel the delivery tube is closed.

Jars filled with gas may be left standing on the bottom of the trough till required for use; test tubes should be secured by the use of the leaden ring. In removing a vessel from the trough it should be closed with the thumb or a small plate of ground glass.

Gas, conducting through an ignition tube.—When a substance heated in an ignition tube is to be subjected to a current of gas, the ignition tube is attached directly to the tube delivering the gas. The gas should be turned on gradually to avoid scattering the contents of the tube.

Gas, decantation of.—This may be done over the pneumatic trough by pouring the gas upwards from the vessel containing it into a second vessel filled with water, the mouths of both vessels being entirely immersed during the operation.

Gas generators.—Fig. 22. In some cases a gas may be supplied as it is used, by a self-regulating generator. Hydrogen, carbon dioxide and hydrogen sulphide are best provided in this way by generators figured as above. The narrow tubulated receiver is suspended in a cylinder about 40 cm. deep and 10 cm. in diameter containing dilute acid. The solid materials for the generation of the gas are put in a leaden basket and suspended by a copper wire from the hooked tube that passes through the neck

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of the receiver; this tube serves also as an exit tube for the gas, being closed outside by means of the rubber tube and screw clamp. So long as the exit tube is closed, the materials in the basket are kept by the accumulated gas from contact with the liquid; but when the exit is open the liquid rises in the inner vessel, and, acting on the materials in the basket, keeps up a steady flow of gas.

Gas tube.—Fig. 3. This is a plain glass tube 30 cm. long and 0.5 cm. in diameter, carrying a piece of rubber tubing by which it is attached to the tube delivering the gas; it is used in passing a current of gas through a liquid; it should be carried nearly to the bottom of the vessel, usually a test tube, containing the liquid, in order that the bubbles of gas may rise through a deep column of the liquid.

Glass, manipulation of.—The shaping and bending of glass rods or tubing are operations with which the student ought to become familiar. To bend a tube, hold it in the lamp flame, turning it constantly to secure uniform heating, till it begins to yield at the heated point, then remove it from the flame and slowly bend it to the desired angle. If the tube is large and thin-walled, or if it has to be bent through a large angle, it should be bent at several contiguous points in succession till the desired angle is obtained.

Rods or tubing are cut by making a sharp scratch with the edge of a file at the desired point, and then steadily drawing the two portions apart and, at the same time, applying lateral pressure as if attempting to bend the rod or tube where the file mark was made.

To close a tube at one end, heat it as before, and, removing it from the flame, draw apart the portions on each side of the heated point; finally, melt down the pointed ends in the flame; on blowing in at the open end of the tube while the other end is red hot a bulb may be made on that end.

To blow cavities or pockets in tubes, *fig. 19*, close one end of the tube with a cork, with a small or a pointed flame heat a spot to redness on one side of the tube, at the point where the cavity is to be made, and then blow gently but steadily in at the open end.

The looped tube *fig. 2*, is made by drawing the tube apart when

heated, as though it were to be closed, until it attains a diameter about one fourth of the original, and then, before it has cooled, folding back the narrow portion on itself.

The sharp edges at the end of tubes or rods used for any purpose should be rounded by holding them for a moment in the lamp flame.

Glass plates.—Small plates of ground glass 6 or 7 cm. square.

Glass tubing.—A supply of moderately thick-walled tubing, free from lead, and ranging from 0.5 to 1.5 cm. in outer diameter should be kept on hand.

Glass vessels use of.—Beakers, flasks, test tubes and other glass vessels having thin bottoms may be used in heating liquids. They should not be heated above the level of the liquid within them nor brought while hot in contact with cold surfaces or cold liquids; large vessels should be placed on the sand bath or on wire gauze rather than over a naked flame. A sediment at the bottom of a vessel containing a liquid is apt to cause a peculiar jarring or *bumping* of the vessel when heated; to avoid danger in such a case the liquid should be constantly stirred or shaken while it is being heated. Test tubes in which dry substances are to be heated should be made perfectly dry before the operation, and, during its continuance, should be so inclined as to prevent any liquid which may condense in the upper part of the tube from flowing back over the heated portion.

Hydrogen sulphide tube.—See *Gas tube*.

Ignition.—This term is generally applied in chemical work to the strong heating of a dry substance in a closed or partly closed vessel.

Ignition tube.—A plain glass tube 16 to 20 cm. long and 1 to 1.3 cm. in diameter, used to contain substances which are to be strongly heated (ignited) in a current of gas. Substances may be readily deposited in such a tube by means of a long narrow slip of writing paper less than twice the inner diameter of the tube in width; the slip is doubled lengthwise with a sharp crease, in one end of the trough thus formed the substance is put, and, when pushed to the proper point in the tube, is deposited by simply rolling the tube half way round.

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Pockets or cavities are sometimes required in ignition tubes; they should not be more than 1 cm. long and 0.5 deep. Several of these cavities are sometimes required in a single tube. Fig. 19. See *Glass, manipulation of*.

Jars, or cylinders.—Wide-mouthed ones of 60 to 500 c.c. (2 oz. to one pint) capacity are required for gas experiments; they should never be heated.

Lamp.—Where the laboratory is supplied with gas the Bunsen burner, *Fig. 1 d*, can be used for all purposes. If alcohol is used it will be necessary to have, in addition to the ordinary spirit lamp for each student, two or three Berzelius lamps for general use in experiments requiring greater heat.

Lamp stand.—See *Ring stand*.

Leaden Rings.—*Fig. 1 g.* These are cut with a saw from lead pipe, and should be of such diameter as to slip readily over the bottom of a large test tube but not over the lip; they may be fitted to smaller tubes by bending. They are used for retaining test tubes in an upright position while inverted in the pneumatic trough or elsewhere.

Lens.—A small magnifying glass folding into a horn case.

Looped tube.—*Fig. 2.* Used to retain a drop of liquid to be exposed to the action of a gas evolved in a test tube. The loop permits the disposition of the drop in a thin film thus exposing greater surface to the action of the gas. See *Glass, manipulation of*.

Magnet.—A small horse-shoe magnet is occasionally needed. One small one will serve the purpose of the laboratory.

Matress.—A tube of glass closed at one end (see *Glass, manipulation of*) used for containing substances which are to be strongly heated without free access of air. It may be 6 to 8 cm. long and 0.5 to 0.8 cm. in diameter; larger sizes are required in special cases.

Measuring.—The denominations of the metric system will be found in the table below together with their approximate values in common measures.



$\frac{\text{inches} \times 5}{2} = \text{cms}$

$\frac{\text{cms} \times 2}{5} = \text{inches}$

INTRODUCTION.

xxi.

TABLE OF WEIGHTS AND MEASURES—METRIC SYSTEM.

Linear Measures.

Decimetre, equals	0.1	Metre	Decametre, equals	10 Metres
Centimetre, “	0.01	“	Hectometre, “	100 “
Millimetre, “	0.001	“	Kilometre, “	1000 “

Measures of Capacity.

Decilitre, equals	0.1	Litre	Decalitre, equals	10 Litres
Centilitre, “	0.01	“	Hectolitre, “	100 “
Cu. centimetre, “	0.001	“	Kilotitre, “	1000 “

Measures of Weight.

1 gramme equals weight of 1 c. c. of pure water at 4° C.

Decigramme, equals	0.1	gm.	Decagramme, equals	10 gms.
Centigramme, “	0.01	“	Hectogramme, “	100 “
Milligramme, “	0.001	“	Kilogramme, “	1000 “

Abbreviations.

Mgm.—milligramme.	Mm.—millimetre.
Gm.—gramme.	Cm.—centimetre.
Kilo.—kilogramme.	C. c.—cubic centimetre.

Approximate relations between English and metric denominations.

I Kilo. equals	2.2 lbs. av. ;	I lb. av. equals	454	gms.
I Gm. “	15.4 grains ;	I grain “	64.8 mgms.	
I Gm. “	0.035 oz. av. ;	I oz. av. “	28.35	gms.
I Litre “	2.1 pints ;	I quart “	946	c. c.
I Litre “	33.8 fluid oz. ;	I fl. oz. “	30	c. c.
I Metre “	39.4 inches ;	I inch “	2.54	cm.

Metre scale.—A graduated scale 1 decimetre in length with cm. and mm. subdivisions should be kept on the laboratory table for reference, till the student has become familiar with the linear measures on which all weights and measures in the metric system are based. A copy on paper of the scale (Plate III) may be pasted on a slip of wood for this purpose, with a scale of inches on the other side for comparison.

Mercury trough.—The laboratory should be provided with a small porcelain or iron mercury trough for general use. It should stand in a shallow, wooden trough about half a metre square.

Mortar and Pestle.—Fig. 19. Of porcelain 7 to 9 cm. in diameter, glazed outside but not within, with pestle entirely of porcelain. The mortar should never be heated.

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Pincettes.—Fig. 9. A pair of small brass pliers or forceps. It should have a link of copper wire sliding upon it to hold it in position when closed. Used for holding platinum foil or other objects in the flame.

Platinum foil.—A piece of foil 2 by 3 cm. is used for fusing small quantities of substances at high temperatures. It should not be heated in contact with metals easily reduced. It may be cleaned by fusing potassium bisulphate on it and dissolving the residue in hot water.

Platinum wire.—No. 23 is of about the proper size. It should be turned into a loop or hook at one end. Used for flame-coloration or bead tests. Clean it in the same way, and use it with the same precautions as in the case of platinum foil. When properly cleaned it should yield no tinge to the flame after it has been held in it for a moment. It is usually attached by fusion to a handle of glass tubing.

Pneumatic trough.—A trough of sheet zinc 14 by 14 by 25 cm. or a plain dish of white earthenware 20 cm. in diameter, fig. 15, may be used. It is indispensable in the collection and transfer of gases. See *Gas, collection of, etc.*

Pocket lens.—See *Lens*.

Precipitation.—This term is applied to the process by which a substance in solution is made to separate in the solid condition. The solid is technically known as the *precipitate*.

Quantitative manipulation.—In conducting a process that requires the accurate weighing of any of the products the greatest care must be taken to avoid loss of substance during the process. Where it is required to pass a gas through a solution containing a substance to be weighed, there is danger that minute quantities of the substance may be thrown out of the vessel by the bubbles of escaping gas; the same risk is incurred during the boiling or effervescence of a liquid. In all such cases the vessel should be covered with a watch glass, from the surface of which any ejected portion of the liquid may be rinsed back into the beaker with the jet of the washing bottle, before proceeding to take the next step in the operation.

The sides of the vessel should also be washed down in the same way.

In case a precipitate is transferred from a beaker or other vessel to a filter, the mixture of liquid and precipitate should be conducted into the filter by means of a glass rod held against the lip of the beaker and directed into the filter; the last portion of the precipitate, if it adheres too firmly to be completely removed by the jet of water, should be loosened by a short piece of soft rubber tubing slipped over the end of a glass rod. No pains should be spared to secure the transfer of every visible particle of the precipitate from the beaker to the filter.

Ring stand.—Fig. 1 a. The iron ring stand is used as a support for vessels when they are heated, and for attaching the holder for test tubes, matrasses, or ignition tubes.

Rubber stoppers.—Vessels may be more perfectly closed with these than with corks, but they are more expensive and less able to withstand the effects of heat.

Rubber tubing.—This is used whenever flexible connections are to be made between sections of glass tubing. It should not be left for any length of time in contact with strong acids or alkalies, and should be washed by passing a current of water through it after having been used. Tubing of 4 to 6 mm. in diameter is best suited for small apparatus, while that of 0.8 to 1 cm. in diameter is required for the adapter. A special quality of good soft tubing is required in certain cases. See *Ball valve*.

Safety tube.—In cases in which a combustible gas, such as hydrogen or hydrogen sulphide, is used in the vicinity of a lamp, as in passing it through a heated ignition tube, it is advisable to pass the gas first through a safety tube, placed near the generator. This may be made, according to Fresenius, by cutting out small disks of fine wire gauze and packing a layer of them 1 to 2 cm. in thickness in a glass tube with a bore a trifle smaller than the disks. The access of flame to the gasometer in case an explosive mixture should be formed is thus prevented.

Sand bath.—A flat-bottomed tray or dish of sheet iron 10 cm. wide and 2 to 3 cm. deep may be used; it should be filled with clean sand; when heated by a lamp such an arrangement supplies a moderate and uniform heat, furnishing the most convenient means of heating glass vessels.

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Scales.—A pair of grocer's or apothecary's scales will be required in the laboratory for weighing larger quantities of substances.

Screw clamp.—Fig. 23. This is used to control the flow of liquids or gases in rubber tubing, and is a cheap and effective stopcock.

Spatula.—Fig. 10. A horn spatula is used for transferring precipitates, mixing powdered substances, etc.

Tare.—See *Weighing*.

Test tubes.—Fig. 4. These are thin-bottomed glass tubes which are to be used invariably for experiments with small quantities of liquids, or of liquids and solids, unless other apparatus is specified. Two sizes are used and these will be referred to as *large* and *small* test tubes, respectively. The first are 15 cm. long and of varying width, the second 10 cm. long. In order to insure complete reaction it is necessary in all cases to mix the contents of test tubes, by agitation, after adding a new substance.

Test tube holder.—The holder shown in fig. 1 b is simple and easily renewed, while it can be adapted to several different purposes. It is made of flexible copper wire 1 to 2 mm. in diameter, twisted around a cork about 2 cm. long and thick, for a handle. For long continued operations, the cork may be pierced and slipped over the rod of the ring stand, on which it should move with considerable friction. The flexibility of the wire permits its accommodation to any angle or, by means of the spirals, to any test tube. It is also used as a support for matrasses, ignition tubes, fig. 19, or small flasks.

Test tube cleaner.—A bit of sponge tied to a pine splinter is an effective and cheap test tube cleaner. Long and narrow tubes may be cleaned by bits of sponge attached to flexible copper wire.

Test tube rack.—A wooden stand for holding test tubes.

Thermometer, chemical.—The usual form of the centigrade thermometer used in chemical and physical laboratories.

Triangle.—Fig. 15. Made of iron wire 1 to 2 mm. thick and used to support crucibles or other small vessels on the rings of the ring stand.

Tumbler.—A common tumbler may often be used as a substitute for more expensive glass vessels, but of course it cannot be heated.

V tube.—Made of moderately thick-walled tubing 1 to 1.2 cm. in diameter and with arms about 15 cm. long; it is used for the decomposition of solutions by the galvanic current.

Ventilating closet.—Every laboratory should be provided with a small closet or hood built against the chimney, and having two or three narrow slits cut through the masonry of the chimney from top to bottom of the closet. All work in which acids or fuming liquids are to be heated, as well as that in which offensive gases, like hydrogen sulphide or chlorine, are used, should be confined to this closet.

Washing apparatus.—Glass or porcelain vessels are most easily cleaned immediately after having been used, and by rubbing with the hands or with a soft sponge in a stream of water. For deep and narrow vessels, a piece of sponge tied to a pine stick is used. Strong acid or sodium hydrate is used to dissolve adhering matters not soluble in water.

Wash-bottle.—Fig. 11. This is of constant use on the laboratory table for washing precipitates, rinsing vessels, or supplying small quantities of distilled water. The orifice of the jet tube should be less than 1 mm. in diameter. A piece of rubber tubing may be used to attach the jet to the longer tube to permit of its being turned in any direction or being changed for a jet of different bore.

Watch glasses.—Fig. 8. Glasses of 5 to 7 cm. in diameter should be used. They should not be heated except on the sand or water bath.

Water bath.—The smallest size, of copper, sold by dealers, will answer. A small evaporator set on a small glass triangle within a large evaporator in which water is kept boiling may be substituted for the rather expensive copper bath.

Weighing.—The following directions apply only to the quantitative work in chapter XXI. Put the substance to be weighed on the left-hand pan, the weights on the right, beginning with the largest weight, unless confident that it is too heavy. When the

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oscillations on either side of the o mark are nearly equal, each one being a little less than the preceding one, the weight may be recorded. When a substance is to be weighed in a small beaker, crucible or watch glass, the *tare* of the vessel used should first be taken ; to this end put a small homoeopathic vial, of less weight than the vessel, on the weight pan, and along with it small shot, till the vessel in the other pan is nearly balanced ; then add small bits of copper foil till the pans are in equilibrium. The shot and foil are then to be put into the vial and the tare is ready for use whenever the same vessel is used again in weighing.

The vial may be stoppered, when not in use, with a cork on which the name or number of the vessel it balances may be written ; of course the cork is to be removed when the tare is to be used. The tare of a vessel being thus taken once for all, any additional weight required on the pan represents the weight of the contents of the vessel on the other pan.

In weighing out with accuracy a given quantity, as 5 gms. for instance, of a dry powder, it is most convenient to proceed as follows : after having taken the tare of the vessel in which the substance is to be weighed, put the weight desired, 5 gms. in the supposed case, in the weight pan, and raise the beam of the balance so that it may swing and allow the needle to point a little to the left of the o point ; while the beam is held up in this manner slowly pour the powder from a small dry test tube into the vessel on the right-hand pan till the needle swings to the other side ; then, with a small spatula or pen-knife blade, take out the excess of powder, in successive small quantities, till the right weight is obtained.

Weights.—One set will be required for the large scales, running from 1 gm. to $\frac{1}{2}$ kilo. For the quantitative work, a small set running from 1 mgm. to 50 gms. will answer.

Y tube.—Fig. 7. This is used to bring together two gases in the ignition tube from separate generators or reservoirs.

APPARATUS REQUIRED BY EACH STUDENT.

It will be found convenient to supply each student with the following set of apparatus, when he begins his practice.

Adapters, 2; 1 blue glass, 1 wide-mouth cork-stop. 250 c. c. bottle, 1 crucible No. 8, 1 9 cm. cylinder, 1 deflagrating cup, 1 exit

tube, 2 evaporators, 5 cm. and 9 cm. diam., 1 pack small filters, 1 rubber finger cap, 2 flasks, 60 and 120 c. c., 3 funnels 4-8 cm. diam., 1 gas tube, 2 glass rods 15 cm. long, 1 ignition tube, 1 lamp and rubber tube, 2 leaden rings, 1 looped tube, 6 mattresses, 1 mortar and pestle, 1 pincettes, 1 platinum cup, 2 platinum wires, 1 fine and 1 coarse, 1 sand bath, 1 spatula, 1 stand of iron, with rings and spiral holder, 6 10 cm. test tubes, 6 15 cm. test tubes, 1 test tube holder, 1 test tube rack, 1 wire triangle, 1 wash bottle, 2 watch glasses, 4-5 cm., 1 Y tube.

The pieces of apparatus named in the following list may be loaned as required for special experiments, to be returned at once, as soon as used. A stock consisting of one piece of each kind for every ten students, will probably be sufficient, except in case of beakers and crucibles, which are liable to be broken.

Drying tubes, bottle gasometers, crucibles large size, files, filter stands, glass tubes, jars, lenses, magnets, pneumatic troughs, thermometers, V tubes, water baths.

Of the other pieces of apparatus mentioned in Section II, one of each kind for general use will suffice for any ordinary number of students.

§ III.

CHEMICALS.

The following list of chemicals includes everything that is needed for the performance of the experiments in the chapters that follow.

In case an aqueous solution of the chemical is required, the number of grammes to be dissolved in 100 c.c. of water to make a concentrated or saturated solution is set against the name of the chemical; for a dilute solution, this concentrated solution may be diluted with twice its volume of water, and, for a very dilute solution, with four or five times its volume. Unless otherwise directed, use the *dilute* solution in the experiments.

If the substance has to be prepared in the laboratory, directions are given for the most convenient method of its preparation.

Any special precautions to be observed in using the substance are given briefly.

In case nothing is to be done but to purchase the chemical and keep it in bottles till wanted for an experiment, or if it can be

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readily procured at any time when wanted, nothing more is given than its name.

In order to avoid excessive consumption of material, the quantities to be taken are given in the description of each experiment; but unless especially directed to measure or weigh the quantities accurately, the numbers are to be taken only as approximate measures. For this purpose it will be safe to consider, in the case of crystallized substances or dry powders, that somewhat less than 1 c.c. weighs 1 gm., and that a like weight of metal will make a fragment about as large as a pea. A cubic centimetre of any substance, liquid or solid, will fill a 10 cm. test tube of about the average width, 1.3 cm., to the height of 1 cm.; the capacity of test tubes of the larger size, 15 cm., is about twice as great. The term *granule* is generally meant to indicate a quantity of a solid that will occupy the volume of a 2 mm. cube. A very little practice will enable the student to estimate with the eye and without any measurement the volume of a substance required, with sufficient accuracy.

The term *granule*, *gramme* (gm.), *fragment* or *bit*, is always to be taken as referring to a chemical in the solid form, while the term *drop* or *cubic centimetre* (c.c.) is always to be understood as referring to a solution of the substance, or a liquid.

In the case of the three acids, hydrochloric, nitric and sulphuric, only the symbols are given in the description of experiments; the symbol is printed in full-faced type, as **HCl**, for concentrated acid, and in plain type, as HCl, for dilute acid.

In the formula of the substance, the water of crystallization is not included.

Acid, acetic, $\text{HC}_2\text{H}_3\text{O}_2$.

- boric (or boracic) H_3BO_3 .
- hydrochloric, **HCl**, concentrated, pure.
- — — HCl, dilute. To 1 part of concentrated acid add 3 or 4 parts of water.
- nitric, **HNO₃**, concentrated, pure.
- — — HNO_3 . To 1 part of concentrated acid add 3 or 4 parts of water.
- oxalic, $\text{H}_2\text{C}_2\text{O}_4$.
- pyrogallic, $\text{C}_6\text{H}_5\text{O}_3$. For use in absorbing oxygen, dissolve 1 gm. in 20 or 30 c.c. of dilute potassium hydrate.

Acid, sulphuric, H_2SO_4 , concentrated (oil of vitriol).

- sulphuric, H_2SO_4 , dilute. To 4 parts of water add 1 part of concentrated acid, slowly and with constant stirring.
- sulphurous. See sulphurous oxide.
- tartaric, $H_2C_4H_4O_6$.

Albumen. Sufficiently pure in white of egg.

Alcohol, C_2H_5HO .

Alum, ammonium iron, $(NH_4)_2SO_4 \cdot Fe_2(SO_4)_3$. 15.

- chromic, $K_2SO_4 \cdot Cr_2(SO_4)_3$. To dissolve in water, it should be finely powdered and dissolved in cold water.
- Heat partially decomposes the salt. 15.

- common, $K_2SO_4 \cdot Al_2(SO_4)_3$. 20.

Aluminum sulphate, $Al_2(SO_4)_3$.

Ammonia gas, NH_3 . Mix equal parts of dry ammonium chloride and slaked lime, powdered separately before mixture; heat the mixture gently in a test tube, in the flame, or by immersing the lower end of the tube in hot water in a beaker. 1 gm. of ammonium chloride fully decomposed should yield over 200 c.c. of gas.

Ammoniacal cuprous chloride. Heat 5 gms. of metallic copper with 15 c. c. of HCl , and 5 c. c. of HNO_3 till the copper is dissolved and evaporate the solution to crystallization; if a brown crust of basic salt appears, stir the liquid and add a few drops of HCl . Then to this concentrated solution add 3 gms. of copper, and 2 c. c. of water, and heat the mixture for ten minutes, filter, pour the filtrate into a large excess of water, collect the white precipitate of cuprous chloride on a filter, wash it quickly, dissolve it in 10 to 15 c. c. of ammonium hydrate, and keep in a glass-stoppered bottle, in a dark closet.

Ammonio ferric chloride. Used in experiments requiring ferric chloride. 20.

Ammonium acetate, $NH_4C_2H_3O_2$. 30.

- bromide, NH_4Br . 10.

- carbonate, $(NH_4)_2CO_3$. The solution should be made without application of heat, and 10 c.c. of ammonium hydrate should be added to the solution for every 10 gms. of carbonate dissolved. Use the concentrated solution for the reagent. 20.

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Ammonium chloride, NH_4Cl .	25.
— hydrate, NH_4HO (aqua ammonia).	
— nitrate, NH_4NO_3 .	30.
— oxalate, $(\text{NH}_4)_2\text{C}_2\text{O}_4$. Use the concentrated solution for the reagent.	10.
— sulphate, $(\text{NH}_4)_2\text{SO}_4$.	30.
— sulphide, $(\text{NH}_4)_2\text{S}$. Pass hydrogen sulphide through 3 parts of ammonium hydrate as long as the gas is absorbed, and then add 2 parts of ammonium hydrate.	
Antimony, metallic.	
Antimony and potassium tartrate (tartar emetic), $\text{KSbOC}_4\text{H}_4\text{O}_6$.	5.
— sulphide, grey, Sb_2S_3 .	
Arsenious oxide, opaque (common), As_2O_3 . More soluble in water containing a little hydrochloric acid.	5.
— oxide, vitreous, As_2O_3 .	
— sulphide (orpiment), As_2S_3 .	
Asbestos, common, long fibre.	
— platinized. Soak a small tuft, about 1 c.c. in bulk, of asbestos in about 2 c.c. of platinum chloride in a small porcelain crucible till as much as possible of the solution is absorbed, then ignite the tuft in another crucible, at first gently, slowly raising the heat to full redness; the soaking and ignition may be advantageously repeated. The tuft should at once be put into an ignition tube, and it may generally be used in the same tube for several operations.	
Barium carbonate, BaCO_3 . Witherite, mineral.	
— chloride, BaCl_2 . Use the concentrated solution for the reagent.	10.
— nitrate, $\text{Ba}(\text{NO}_3)_2$.	8.
— sulphate, BaSO_4 . Heavy spar, mineral.	
— sulphide, BaS .	
Benzine, (light petroleum naphtha.)	
Bismuth, metal.	
— nitrate, $\text{Bi}(\text{NO}_3)_3$. Dissolve in water acidified with HNO_3 .	10.
Bladder, animal membrane.	
Bone ash.	
Borax, see sodium tetraborate.	

Brass wire, fine, about 1 mm. in diameter.

Brazil wood.

Bromine.

Cabbage, red. To make infusion, cut it up and digest half an hour with its volume of water.

Cadmium chloride, CdCl_2 .

10.

Calcium carbonate, CaCO_3 . Good white marble will answer.

- chloride, CaCl_2 . When dried and ignited it absorbs water with great avidity. It is best kept in a small fruit jar with porcelain-lined or glass cap. 20.

- hydrate, $\text{Ca}(\text{HO})_2$. The laboratory is most conveniently supplied with the solution of this reagent by putting half a kilogramme of freshly slackened lime in a two-litre bottle, filling the bottle with water, shaking the mixture strongly, letting it stand quietly till the supernatant liquid is clear, and then drawing the solution off by a syphon into the stock bottle; the first bottle may at once be refilled with water, shaken, stoppered, and set aside, and when a fresh quantity of the solution is needed, it may be drawn off as before. The same quantity of lime may be treated with water in the same way, several times.

- nitrate, $\text{Ca}(\text{NO}_3)_2$. 20.

- oxide, CaO (lime).

- phosphate, $\text{Ca}_3\text{P}_2\text{O}_8$. Tolerably pure in well-burned bone ash.

- silicate, CaSiO_3 . Tabular spar, mineral.

- sulphate, CaSO_4 . The solution is best made in the same manner as described for the preparation of calcium hydrate.

- sulphide, CaS . May be made by boiling milk of lime (water mixed with excess of slackened lime) with flowers of sulphur; the sulphide crystallizes out of the liquid on cooling, if sufficiently concentrated.

Calico; some bright colors.

Carbon dioxide, (carbonic acid), CO_2 . Most conveniently supplied for the laboratory by means of the self-regulating gas generator (see § II), with dilute hydrochloric acid in the cylinder and marble in the basket.

- disulphide, CS_2 .

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Cement. An excellent cement for covering corks in bottles, as in making the bottle gasometer, is made by digesting together equal parts of pitch and gutta percha, for a long time at a moderately elevated temperature and with occasional stirring.

Chamois skin.

Charcoal, animal.

— common, in powder and in pieces.

Chlorine, Cl. This gas is best made in small quantities in a test tube as it is wanted, and by the following method: Into a large test tube put powdered manganese dioxide to the depth of about 1 cm., pour over it 1-2 cm. of **HCl**, attach an exit tube, by an adapter, and heat very gently; the whole operation should be conducted in the hood. Bleaching powder and HCl may also be used, and in this case no heat is necessary; the first method requires but little heat, and will generally be found to be more convenient, as the gas is evolved at a more uniform rate.

Chrome alum, see alum, chrome.

Cobalt chloride, CoCl_3 .

10.

Copper, metal. Foil, and wire from 0.6 to 1 mm. in diameter.

Cotton.

Cupric chloride, CuCl_2 . May be made by dissolving metallic copper in aqua regia (one part nitric acid and three parts hydrochloric acid), and evaporating the solution to crystallization, with care to avoid overheating the crystalline residue.

20.

— oxide, CuO .

— nitrate, $\text{Cu}(\text{NO}_3)_2$.

10.

— sulphate, CuSO_4 .

25.

Cuprous chloride, Cu_2Cl_3 . Used only in ammoniacal solution.

See ammoniacal cuprous chloride.

Ether, $(\text{C}_2\text{H}_5)_2\text{O}$.

Ferric chloride, Fe_2Cl_6 . The cheaper double salt of ammonium chloride and ferric chloride may in general be used where ferric chloride is required, as the presence of ammonium chloride does not interfere with the reactions of the ferric salt. See ammonio-ferric chloride.

Ferric oxide, powdered, (colcothar) Fe_2O_3 .

Ferrous, acetate, $\text{Fe}(\text{C}_2\text{H}_5\text{O}_2)_2$. Digest iron wire or small nails with acetic acid. The solution oxidizes readily on exposure to the air.

- sulphate, FeSO_4 . The solution oxidizes readily on exposure to the air; therefore when it is essential that it should be quite free from ferric salt, a few drops of stannous chloride should be added, just previous to using it. 15.
- sulphide, FeS . The fused sulphide is required. No other can be used in the self-regulating generator.

Filters. Those of white, German paper can be bought in packages, of 1000, already cut. The three sizes, 7, 10, and 12 cm. in diameter respectively are most used.

Foil. It is essential that several of the metals, such as copper, zinc, silver, etc., be used in the form of narrow strips of very thin foil, in many of the experiments. If there is not a set of rolls in the laboratory, or in the possession of some worker in metals in the neighborhood, foil should be ordered of the dealer, in the cases where foil is mentioned against the name of a metal. When the metal can be procured in the form of wire, this, of about 1 mm. in diameter, is easily rolled into foil of the proper width.

Glass, powdered.

Glue, animal.

Glycerine.

Graphite, powdered.

Gum arabic.

Gun cotton.

Hydrogen. Best supplied for the laboratory in the self-regulating generator, by the action of H_2SO_4 on zinc (spelter). The tube leading from the apparatus should be provided with a safety tube containing a layer 2 or 3 cm. thick of fine wire gauze disks. See safety tube, § II.

- sulphide, H_2S . Best supplied, like hydrogen, in the self-regulating generator, by the action of H_2SO_4 on *fused ferrous sulphide*.

Ice.

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Indigo solution. To 8 parts of H_2SO_4 , add slowly and with constant stirring 1 part of finely powdered indigo, and heat the mixture to about 100°C . for an hour; then let it cool and pour slowly into 20 parts of water.

Iodine.

- fracture of. Shake up 1 part of iodine with 12 or 15 parts of alcohol, by weight.

Iron, metal. Required in the form of small pieces of cast iron, of clean filings, and of foil.

Lampblack.

Lead acetate, $\text{Pb}(\text{C}_2\text{H}_5\text{O}_2)_2$.

20.

- carbonate, PbCO_3 .
- chloride, PbCl_2 . Prepared by adding HCl to lead acetate solution, collecting the precipitated chloride on a filter, and washing it with cold water.
- iodide, PbI_2 . Prepared by adding potassium iodide solution to lead acetate solution, with care to stop as soon as a precipitate ceases to be formed, and collecting the precipitate on a filter and washing it with cold water.
- metal required in the form of foil and freshly cut shavings.
- nitrate, $\text{Pb}(\text{NO}_3)_2$.
- oxide, PbO (litharge).
- paper. Prepared by dipping slips of filter paper in lead acetate solution; the paper may be dried and kept in well-stoppered bottles.
- sulphate, PbSO_4 .
- sulphide, PbS . Prepared by passing a current of hydrogen sulphide through lead acetate solution, collecting the precipitate by filtration and washing as usual.
- tartrate, $\text{PbC}_4\text{H}_4\text{O}_6$. Add potassium bitartrate solution to solution of lead acetate as long as a precipitate is formed, and filter, wash and dry the precipitate as usual.

Lithium chloride, LiCl .

10.

Litmus.

- paper. Prepared by dipping strips of filter paper in red and blue litmus solutions, for red and blue paper respectively, drying the slips and keeping them protected from the light and from the fumes of the laboratory.

Litmus solutions, blue and red. Boil litmus with water in an evaporator, adding more water from time to time to replace what is boiled away, and filter through a ribbed filter; divide the solution into two portions, and to one portion add a few drops of sodium hydrate solution, and to the other a few drops of HCl, till the solution has a clear wine red color. Add a drop or two of carbolic acid to prevent decomposition.

Logwood.**Magnesium carbonate, $MgCO_3$.**

- chloride, $MgCl_2$. 30.
- metal. In the form of ribbon.
- oxide MgO .
- sulphate, $MgSO_4$. 30.

Manganese dioxide, MnO_2 . Black oxide of manganese.

- sulphate, $MnSO_4$. 20.

Mercuric chloride, $HgCl_2$.

- nitrate, $Hg(NO_3)_2$. 5.
- iodide, HgI_2 . Add potassium iodide solution to mercuric chloride solution only as long as a precipitate is formed, filter and wash as usual.
- oxide, HgO .

Mercurous nitrate, $Hg_2(NO_3)_2$.

5.

Mercury, metal.**Milk.****Nickel sulphate, $NiSO_4$.**

20.

Nitric oxide, N_2O_3 . In one arm of a large U tube suspend a roll of copper foil, and close the mouth of this arm with a rubber cork carrying a short glass tube, with a rubber tube closed by a screw clamp; nearly fill the other arm of the tube with HNO_3 ; on opening the clamp the acid rises to the copper, and the gas is evolved.

Nitrogen. Provide a small bottle with a cork carrying two tubes, one of them passing just to the lower end of the cork, the other extending to the bottom of the bottle and dipping into a layer of strong ammonia, one centimetre in depth. Force a stream of air from a gasometer or rubber bag through this ammonia, and then over copper turnings

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heated to redness, and into the receiver for the gas. A layer of turnings 7-8 cm. long in a short piece of combustion tube, heated by two Bunsen burners is sufficient, and the same copper can be used repeatedly.

Nitrous oxide, N_2O . Best made in small quantities as wanted, by heating ammonium nitrate in a test tube; 1 gramme of the salt will make more than a large test tube full of gas.

Oil. Either whale, lard, or olive oil will answer.

Oxygen. Heat together, in a copper or iron retort made for this purpose and sold by dealers, a mixture of 1 part of powdered manganese dioxide or ferric oxide and 2 of potassium chlorate, and collect the gas in a large rubber gas bag.

Paper, salted, albumenized. Such as photographers use.

— printing, unsized.

— filter. Get white German filter paper.

Paraffine.

Phosphorus, common. This substance should always be kept under water, should never be allowed to come in contact with the skin, being always handled with the pincettes, and all residues left after an experiment should be burned; only a granule or two should be used in an experiment. To granulate it, drop small pieces into a mortar containing hot water, and when it is fused pour off a portion of the water with care not to expose the phosphorus to the air; then drop in small pieces of ice till the whole is ice-cold, and, finally, by gentle pressure with the pestle, break up the sheet of phosphorus, now quite brittle, into granules of from 1 to 2 mm. in size.

— red or amorphous.

Platinum chloride, PtCl_4 . The solution may be obtained of dealers. Dilute it with 3 or 4 parts of water. A bottle should be provided for the reception and preservation of all residues from experiments requiring the use of platinum.

Potassium acetate, $\text{KC}_2\text{H}_3\text{O}_2$.	30.
— bromide, KBr .	10.
— bisulphate, KHSO_4 .	20.
— bitartrate, $\text{KHC}_4\text{H}_4\text{O}_6$.	30.

— carbonate, K_2CO_3 .	30.
— chlorate, $KClO_3$.	8.
— chloride, KCl .	25.
— cyanide, KCy . Very poisonous.	30.
— dichromate, $K_2Cr_2O_7$.	8.
— ferrocyanide, $K_4(FeC_6N_6)$ or K_4Cf_y .	25.
— hydrate, KHO . Fused in sticks.	30.
— iodide, KI .	10.
— metal. Must be kept in benzine, and should not be handled with wet instruments or brought in contact with water in any way except in the course of an experiment. Use only a granule or two, cut off with a knife, for an experiment.	
— nitrate, KNO_3 .	20.
— permanganate, K_2MnO_8 .	10.
— sodium carbonate. A mixture of equal parts of the two carbonates fuses more easily than either carbonate alone, and is used in some experiments requiring fused alkaline carbonates.	
— sulphate, K_2SO_4 .	8.
— sulphide, K_2S . May be made by passing hydrogen sulphide through a solution of potassium hydrate as long as the gas is absorbed and then adding a quantity of potassium hydrate solution equal to that first taken.	

Potassium sulphocyanate, $KCNS$. 10.

Pumice stone.

Quinine sulphate.

Rosin.

Sand. Clean, fine, river or sea sand.

Saw dust. Clean and fine.

Silver chloride, $AgCl$.

— metal. Required in the form of foil.

— nitrate, $AgNO_3$.

— — iodized solution, as used by photographers.

— residues. A bottle should be provided for the reception and preservation of all the residues of experiments requiring silver compounds.

— sulphide, AgS . Conduct a current of hydrogen sulphide through silver nitrate solution as long as a precipitate is

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formed, filter, and wash the sulphide in the usual manner and dry it.

Soap.

Sodium acetate, $\text{NaC}_2\text{H}_3\text{O}_2$. 30.

— bicarbonate, NaHCO_3 . Dissolve only in cold water. 8.

— carbonate, cryst., Na_2CO_3 . 30.

— — pure, sicc. 6.

— chloride, NaCl . 30.

— hydrate, NaHO . 30.

— metal. As the metal oxidizes rapidly in the air it should be kept in a bottle with commercial benzine in sufficient quantity to cover it. The same precautions in regard to contact with water should be observed as in the case of potassium. To granulate the metal put a lump of it in the mortar, cover it with benzine and flatten it out with the pestle to a sheet about 1 mm. thick; then, removing it from the liquid, cut it with the scissors into ribbons which are allowed to fall back into the benzine, and finally cut these ribbons into granules 2 or 3 mm. square.

— nitrate, NaNO_3 . 30.

— phosphate, Na_2HPO_4 . 20.

— tetraborate, $\text{Na}_2\text{B}_4\text{O}_7$. 5.

— silicate. Water-glass.

— sulphate, Na_2SO_4 . 20.

— sulphite, Na_2SO_3 . 25.

Stannic chloride, SnCl_4 . Oxymuriate of tin. Add HNO_3 drop by drop, to a boiling solution of stannous chloride till a drop of the liquid gives no reaction with mercuric chloride solution.

Stannous chloride, SnCl_2 . Muriate of tin. Easily prepared by dissolving granulated tin in HCl to which a few drops of HNO_3 have been added. A little tin should be kept in the bottle containing the solution, to prevent the formation of stannic salt.

Starch, $\text{C}_{12}\text{H}_{22}\text{O}_{10}$.

Stearine candles.

Strontium carbonate, SrCO_3 .

— nitrate, $\text{Sr}(\text{NO}_3)_2$. 20.

- Sugar, $C_{12}H_{22}O_{11}$. 20.
- Sulphuretted hydrogen. See hydrogen sulphide.
- Sulphur flowers. Instead of attempting to clean a tube in which sulphur has been fused, it is better to put the tube aside and reserve it for future experiments with the same substance.
- Sulphur, roll.
- Sulphurous oxide, SO_2 . Best made in small quantities as wanted, by moistening 1 or 2 gms. of charcoal powder in a test tube with H_2SO_4 , and heating gently.
- Tapers, paraffine. Dip lamp wicking into melted paraffine, in an evaporator, and when cold cut it into 10 cm. lengths.
— wax.
- Test papers. Lead, red litmus, blue litmus, and turmeric paper. The colored papers should be protected from the light, and all should be protected from laboratory fumes. In testing a gas produced in an experiment, it is convenient to wrap the paper around a moistened glass rod, on which it may be plunged into the test tube, or exposed in any other way to the gas to be tested. If in doing this a blue paper has been partially reddened by acid on the fingers, it may be held on the rod in the mouth of the ammonium hydrate bottle for an instant; or to redden a blue paper it may be exposed to the fumes from the HCl bottle for an instant only.
- Tin. Required in the form of foil and of ordinary granulated tin.
- Turmeric tincture. Digest clippings of tumeric root in alcohol, and filter.
- Turpentine, oil or spirits of.
- Varnish. Common shellac.
- Watch springs. Old ones can be obtained of jewellers.
- Water, distilled. Every laboratory should be provided with a small copper boiler and tin worm, for the preparation of distilled water.
- Zinc carbonate, $ZnCO_3$.
— chloride, $ZnCl_2$. 20.
— metal. Foil, granulated zinc, and spelter or block zinc required. The foil may be rolled out of common sheet zinc.

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Zinc nitrate, $\text{Zn}(\text{NO}_3)_2$.	30.
— phosphate.	
— oxide, ZnO .	
— silicate. Calamine, mineral.	
— sulphate, ZnSO_4 .	20.

§ IV.

SUGGESTIONS TO TEACHERS.

It will be recognized by the teacher at the outset that many experiments in chemistry involve elements of danger which can only be eliminated by the exercise of care and discretion, and that every experiment must be performed in a certain way in order that it shall surely lead to the intended result. It has been the aim of the authors so to caution and direct the student that, however unskilled, he may be enabled to work with safety and success.

As a further precaution the teacher should secure attention to the following general directions:

All experiments in which heat is applied in any way to hydrogen or to a mixture of gases containing hydrogen, either in a test tube, ignition tube, or any other piece of apparatus, must be conducted carefully in every particular as described in the book; in many cases an explosion may be expected, which however will usually be very slight.

Other experiments in which more or less violent explosions may possibly though not always necessarily take place, and which should also be very carefully performed, are the following; the student should mark them in his book before beginning his work:

Page 3, ex. 4; p. 5, ex. 10; p. 31, ex. 5; p. 33, ex. 3; p. 34, ex. 6; p. 36, ex. 2; p. 40, ex. 3 and 5; p. 42, ex. 1; p. 59, ex. 5; p. 61, ex. 2 and E 1; p. 65, ex. 3.

All experiments in which chlorine is used, or in which a liquid containing much free hydrochloric or nitric acid is heated, should be conducted in the hood.

In heating a liquid in a test tube the mouth of the tube should be so turned away from the operator as to prevent possible injury

by spurting; and before smelling the contents of a tube or looking into it while held vertically after heating, as may sometimes be necessary, it should be removed from the lamp and agitated for a moment.

In adding one liquid to another in a test tube a very small quantity should be added at first and the contents should be thoroughly agitated so as to guard against any violent action on further addition.

The student should be required first of all to read carefully §§ I and II of the introduction, so much of § III as refers to the rough measurement of quantities, page xxviii, and the explanation of the full-faced symbols, and the first part of § IV referring to precautions to be observed in performing the experiments. His attention should be specially directed to the statement on page xxiv under the item *test tubes* in regard to the use of these when other directions are not given. When he reaches the first chemical equation on page 13, 19 or 20 he should turn to chapter XIV and read the paragraphs on symbols, atomic weights, quantivalence and electrical character of the elements, and, with the aid of these explanations of the methods of writing equations, study all the equations he meets with as he progresses with his work; when he reaches chapter VI he should begin to attempt to write out equations not given, as well as to study those that are given.

To perform properly all the experiments given in illustration of each principle more time is required than most students may wish to devote to the study; and it is in any case better to perform a few experiments carefully, and even repeatedly, if clear and decisive results are not obtained at first, than to go over a great deal of ground hastily and in imperfect manner. Four selected lists of experiments are therefore given in the following table, for the convenience of the teacher who may have to provide such shorter courses of work. Each list comprises at least one illustration of every principle, and for the briefest course of practice any one of these lists may be taken alone; for a longer and more satisfactory course two sets may be taken, and for this purpose the selection is so arranged that the first and third, or the second and fourth sets, contain very few experiments in common.

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Chapter	Letter:	Number.				Chapter	Letter:	Number.			
		I	II	III	IV			I	II	III	IV
I	A	1	2	3	4	X	A	1	3	6	7
	B	1	2	3	2		B	1	3	4	2
	C	1	4	8	2		C	1	2	3	7
II	A	1	3	3	2	XI	A	1	4	2	6
	B*	1	2	3	4		B	1	3	2	3
	C	1	3	4	5		C	1	2	3	4
	D	1	4	2	5		D	1	1	2	2
	E	1	1	5	3		E	1	4	2	5
	F	1	2	2	2		F	1	3	3	4
	G	1	2	2	2		G	1	3	2	4
III	A	1	3	6	2	XII	H	1	1	1	1
	B	1	1	4	6		I	all	all	all	all
	C	1	2	2	2		A	1	2	1	2
	D	1	2	2	3		B	all	all	all	all
	E	1	2	2	4		C	1	2	3	1
	F	1	1	3	2		D	1	2	2	2
IV	A	1	4	2	6	XIII	E	1	2	all	all
	B	1	4	2	3		F	1	2	3	4
	C	1	4	2	2		G	1	2	2	2
	D	1	2	2	2		H	1	1	2	2
	E	1	2	2	2		I	1	2	3	1
	F	1	2	3	1		K	1	2	2	2
	G	1	2	3	1		L	1	2	3	1
	H	1	2	3	1		A	1	4	2	5
	I	1	2	3	1		B	1	2	3	4
	J	1	2	1	2		C	1	2	3	4
V	A	1	2	7	3	XIV	D	1	2	2	2
	B	1	1	3	4		E	1	2	3	4
	C	1	5	2	4		F	all	all	all	all
	D	1	2	2	2		A	1	2	3	4
	E	1	2	3	4		B	1	2	3	4
VI	A	1	2	4	2	XV	C	1	2	3	4
	B	1	3	2	5		D	1	2	3	4
	C	1	2	3	1		E	1	2	3	4
VII	A	1	5	2	6	XVI	F	1	2	3	1
	B	1	3	2	4		A	1	3	2	3
VIII	A	1	1	2	2		B	1	3	2	8
	B	1	2	3	1		C	1	3	4	5
	C	1	2	3	1		D	1	3	4	5
	D	1	5	2	3		E	1	1	1	1
	E	1	3	2	4		F	1	2	3	1
	F	1	1	3	1		A	1	3	2	6
IX	A	1	1	2	2	XVII	B	1	2	3	1
	B	1	1	2	2		C	1	2	3	4
	C	1	2	3	1		D	1	1	1	1

* Substances.

Chapter.	Letter.	Number.				Chapter.	Letter.	Number.			
		I	II	III	IV			I	II	III	IV
XVII	A	1	1	1	1	XIX	A	1	2	3	1
	B	1	2	2	2		B	1	2	2	2
	C	1	1	1	1		C	1	2	3	14
	D	1	3	2	1		A	all	all	all	all
	E	1	1	2	2		B	1	1	2	2
	F	1	2	3	4						
	G	1 3 7	2 4	5 6	1 4						
XVIII	A	1	2	3	4	XXI	A	1 2	2 3	4	5
	B	1 2	1 2	3	3		B	1 2 6 7	4 8 9	5 11	3 13 14
	C	1	2	2	2						
	D	1 3	2	4	1 3						
	E	1	1	1	1						

In small laboratories where it may be desirable to reduce the variety and quantity of materials required to the lowest limits, the teacher should, before ordering the chemicals decide on one or more sets of experiments to which the class will be confined, and then, as may be done with the aid of the following table, procure only those chemicals that are required for the work selected; in this table a cipher in any column against the name of any chemical indicates that it is used in the set of experiments designated by the numeral at the head of the column. If the cipher occurs in the column headed *liquid* the chemical is required in solution if it is a solid; if the cipher occurs also in the column headed *solid* the chemical is required in the solid form. If the name of the chemical is given in italics it indicates that it must be kept, in the solid form, in glass-stoppered bottles, because hygroscopic, or for some other reason. All the chemicals not so designated may be kept in boxes or in cork-stoppered bottles.

In the first column after the name of the chemical the quantity in ounces that it is advisable to order for a laboratory of ten to fifteen students is given; if the teacher intends to follow but one set of experiments, half the quantities specified will probably suffice.

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OZ.	I		II		III		IV	
	Sol.	Liq.	Sol.	Liq.	Sol.	Liq.	Sol.	Liq.
Acid acetic,	16	o	o	o	o	o	o	o
.. boric,	2	o	o	o	o	o	o	o
.. hydrochloric,	240	o	o	o	o	o	o	o
.. nitric,	240	o	o	o	o	o	o	o
.. oxalic,	6	o	o	o	o	o	o	o
.. pyrogallic,	4	o	o	o	o	o	o	o
.. sulphuric,	320	o	o	o	o	o	o	o
.. tartaric,	4	o	o	o	o	o	o	o
Albumen,								
Alcohol,	64	o	o	o	o	o	o	o
Alum, ammonium iron,	4	o	o	o	o	o	o	o
.. chromic,	4	o	o	o	o	o	o	o
.. common,	4	o	o	o	o	o	o	o
Ammonio-ferric chloride,	4	o	o	o	o	o	o	o
Ammonium bromide,	2	o	o	o	o	o	o	o
.. carbonate,	16	o	o	o	o	o	o	o
.. chloride,	16	o	o	o	o	o	o	o
.. hydrate,	32	o	o	o	o	o	o	o
.. nitrate,	16	o	o	o	o	o	o	o
.. oxalate,	4	o	o	o	o	o	o	o
.. sulphate,	4	o	o	o	o	o	o	o
.. sulphide,	4	o	o	o	o	o	o	o
Antimony, metal,	4	o	o	o	o	o	o	o
.. and pot. tart.,	4	o	o	o	o	o	o	o
.. sulphide,	2	o	o	o	o	o	o	o
Arsenious oxide,	4	o	o	o	o	o	o	o
Asbestos,	8	o	o	o	o	o	o	o
.. platinized,								
Barium carbonate,	4	o	o	o	o	o	o	o
.. chloride,	8	o	o	o	o	o	o	o
.. nitrate,	4	o	o	o	o	o	o	o
.. sulphate,	4	o	o	o	o	o	o	o
.. sulphide,	4	o	o	o	o	o	o	o
Benzine,	4	o	o	o	o	o	o	o
Bismuth,	2	o	o	o	o	o	o	o
Bismuth nitrate,	2	o	o	o	o	o	o	o
Bladder,								
Bladder,	2	o	o	o	o	o	o	o
Bone ash,								
Borax,	4	o	o	o	o	o	o	o
Brass wire,	2	o	o	o	o	o	o	o
Brazil wood,	4	o	o	o	o	o	o	o
Bromine,	2	o	o	o	o	o	o	o
Cabbage, red,								
Cadmium chloride,	2	o	o	o	o	o	o	o
Calcium carbonate,	48	o	o	o	o	o	o	o
.. chloride,	8	o	o	o	o	o	o	o
.. hydrate,								
.. nitrate,	4	o	o	o	o	o	o	o
.. oxide,	80	o	o	o	o	o	o	o
.. silicate,	4	o	o	o	o	o	o	o
.. sulphate,	16	o	o	o	o	o	o	o
.. sulphide,	4	o	o	o	o	o	o	o
Calico,								
Carbon disulphide,	8	o	o	o	o	o	o	o

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	QZ.	I	II	III	IV
		Sol.	Liq.	Sol.	Liq.
Charcoal, animal,		4	0	0	0
common,		0	0	0	0
Cobalt chloride,	2	0	0	0	0
Copper, metal,	16	0	0	0	0
Cotton,		0	0	0	0
Cupric chloride,		0	0	0	0
oxide,	4	0	0	0	0
nitrate,	4	0	0	0	0
sulphate,	32	0	0	0	0
Cuprous chloride,		0	0	0	0
Ether,	16	0	0	0	0
Ferric chloride,		0	0	0	0
oxide,	4	0	0	0	0
Ferrous acetate,		0	0	0	0
sulphate,	16	0	0	0	0
sulphide,	96	0	0	0	0
Glue,		4	0	0	0
Glycerine,		16	0	0	0
Graphite,		4	0	0	0
Gum arabic,		4	0	0	0
Gum cotton,		4	0	0	0
Iodine,	2	0	0	0	0
tincture,		0	0	0	0
Iron, foil, filings,		0	0	0	0
Lamphblack,		0	0	0	0
Lead acetate,	2	0	0	0	0
carbonate,	8	0	0	0	0
chloride,	4	0	0	0	0
iodide,	2	0	0	0	0
metal,	2	0	0	0	0
nitrate,	8	0	0	0	0
oxide,	8	0	0	0	0
sulphate,	4	0	0	0	0
sulphide,	4	0	0	0	0
tartrate,	4	0	0	0	0
Lithium chloride,		1	0	0	0
Litmus,		2	0	0	0
Logwood,		2	0	0	0
Magnesium carbonate,		0	0	0	0
chloride,	4	0	0	0	0
metal,	4	0	0	0	0
oxide,	1	0	0	0	0
sulphate,	4	0	0	0	0
Manganese dioxide,		16	0	0	0
sulphate,	8	0	0	0	0
Mercuric chloride,		4	0	0	0
nitrate,	4	0	0	0	0
iodide,	2	0	0	0	0
oxide,	1	0	0	0	0
Mercurous nitrate,		8	0	0	0
Mercury, metal,		4	0	0	0
Nickel sulphate,		20	0	0	0
Oil,		2	0	0	0
Paper, salted, albumen.		0	0	0	0

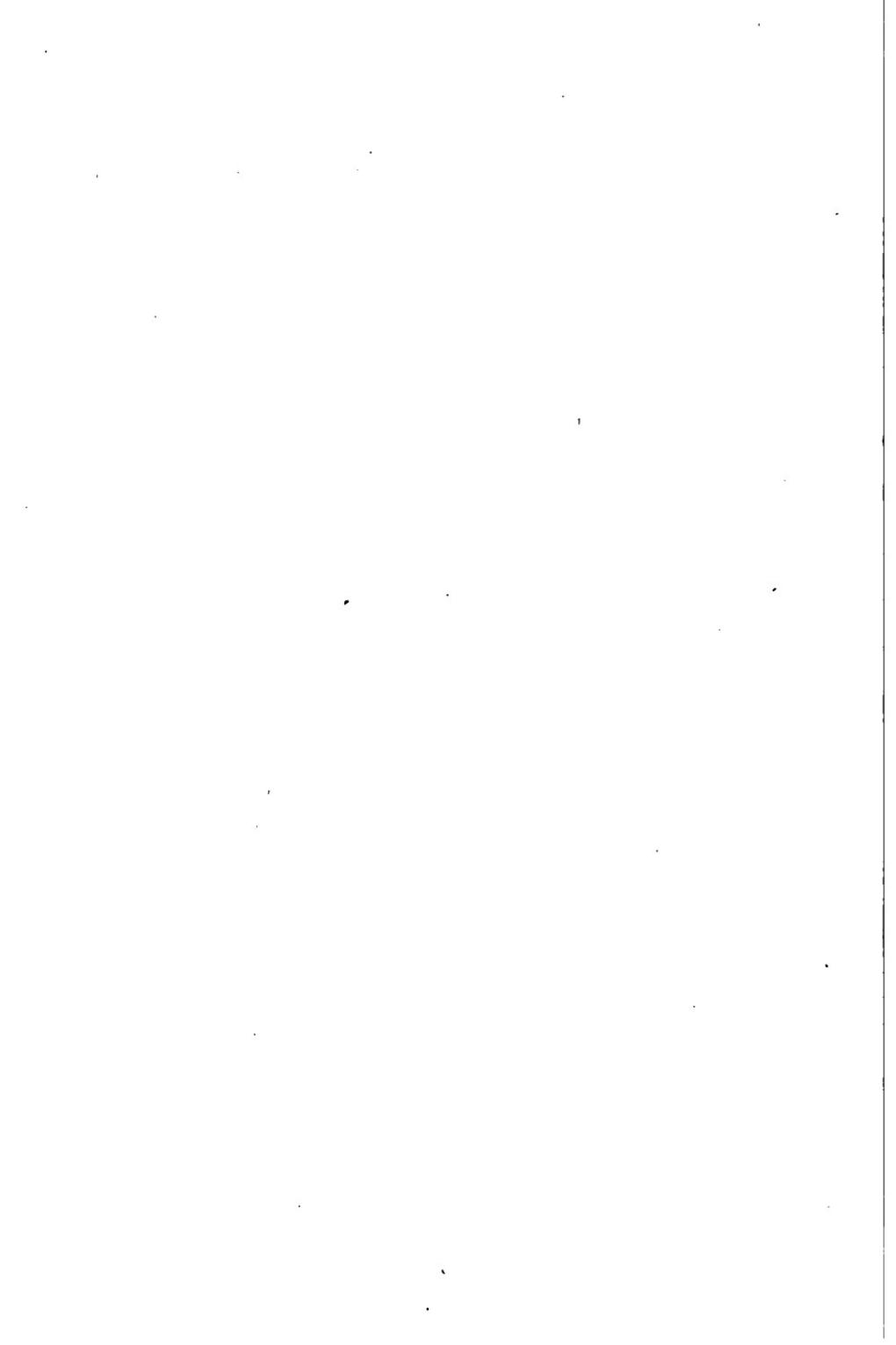
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	oz.	Sol.	I	II	III	IV
		Liq.	Liq.	Liq.	Liq.	Liq.
Paraffine,	16	o				
Phosphorus common,	16	o				
<i>red.</i>	4					
Platinum chloride,	1	o				
Potassium bromide,	2	o				
<i>bisulphate,</i>	8	o				
<i>bitartrate,</i>	16	o				
<i>carbonate,</i>	80	o				
<i>chlorate,</i>	8	o				
<i>chloride,</i>	8	o				
<i>cyanide,</i>	8	o				
<i>dichromate,</i>	4	o				
<i>ferrocyanide,</i>	4	o				
<i>hydrate,</i>	32	o				
<i>iodide,</i>	2	o				
<i>metal,</i>	16	o				
<i>nitrate,</i>	48	o				
<i>permanganate,</i>	2	o				
<i>sulphate,</i>	4	o				
<i>sulphide,</i>	4	o				
<i>sulphocyanate,</i>						
Pumice stone,	16	o				
Quinine sulphate,	16	o				
Rosin,	4	o				
Sand,	4	o				
Silver chloride,	16	o				
<i>metal,</i>	4	o				
<i>nitrate,</i>	4	o				
<i>nitrate, iod. sol.,</i>	2	o				
<i>sulphide,</i>	2	o				
Sodium acetate,	8	o				
<i>bicarbonate,</i>	4	o				
<i>carb. cryst.,</i>	8	o				
<i>carbonate, pure, sicc.,</i>	16	o				
<i>chloride,</i>	16	o				
<i>hydrate,</i>	32	o				
<i>metal,</i>	32	o				
<i>nitrate,</i>	2	o				
<i>phosphate,</i>	8	o				
<i>silicate,</i>	8	o				
<i>sulphate,</i>	8	o				
<i>sulphite,</i>	16	o				
<i>sulphite,</i>	4	o				
Stannic chloride,						
Stannous chloride,						
Starch,						
Stearine (candles),	16	o				
Strontium carbonate,	4	o				
<i>nitrate,</i>	4	o				
Sugar,	16	o				
Sulphur, flowers,	16	o				
Tapers, wax,	16	o				
Tin,	16	o				
Turmeric,	4	o				
Turpentine,	8	o				

	oz.	I Sol.	I Liq.	II Sol.	II Liq.	III Sol.	III Liq.	IV Sol.	IV Liq.
Watch springs,									
Zinc carbonate,									
-- chloride,	4	o							
-- metal, foil,	4								
-- gran.,	8	o	o	o	o	o	o	o	o
-- nitrate,	32	o	o	o	o	o	o	o	o
-- phosphate,	4								
-- oxide,	4	o	o	o	o	o	o	o	o
-- silicate,	4								
-- sulphate,	8	o	o	o	o	o	o	o	o

The student should be required to note the following experiments in his book, as to be performed in the hood.

Page 3, B. 2; p. 4, C. 2; p. 5, C. 11; p. 20, G. 2, 3, 4; p. 21, H. 11, 13; p. 24, A. 2, 3; p. 27, E. 2; p. 29, A. 4; p. 35, B. 3; p. 36, A. 2; p. 38, C. 1, 2; p. 39, C. 4; p. 40, D. 3, E. 1; p. 43, A. 2; p. 44, B. 1; p. 45, C. 1, 2, 3; p. 47, B. 1; p. 52, C. 2; p. 53, E. 1, 2; p. 54, F. 1; p. 55, G. 1, 2, 3, 5; p. 61, B. 2, E. 1, 2, 3; p. 64, L. 1, 2, 3; p. 78, A. 1, 2, 3; p. 87, B. 2, 3; p. 89, C. 2, 3; p. 95, C. 1, 3, 4; p. 122, B. 11, 12, 13, 14.



INTRODUCTORY CHEMICAL PRACTICE.

CHAPTER I

Meaning of the term experiment.—Chemical and physical properties compared.—Evidences of chemical action.

A. Meaning of the term experiment.—An experiment is “an act or operation designed to discover some unknown truth, principle or effect, or to establish it when discovered.”

In chemistry, an experiment consists in bringing together, under certain conditions, objects which either do not come within the sphere of mutual action at all in the natural world, or else not under the particular conditions imposed. The action of

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certain physical agents, as heat, light or electricity, is a necessary condition in many experiments.

Naturally, such an operation cannot serve its purpose unless accompanied by an observation of the results produced and their relation to the conditions of the experiment.

1. Bring together 1 gm. of marble and 2 c.c. of HCl, and after a moment plunge a burning splinter of wood into the upper part of the test tube.

2. Heat 1 gm. of potassium chlorate in a dry test tube, and, when it fuses and gives off bubbles of gas freely, plunge a glowing splinter into the upper part of the tube.

3. Pour 2 c. c. of H_2SO_4 over 1 gm. of common salt and plunge a piece of blue litmus paper into the upper part of the tube, with care not to touch the sides of the tube, or the liquid within it; heat gently and test again with litmus paper.

4. Put together 1 c. c. of barium chloride and 2 c. c. of ammonium carbonate, shake the tube and slowly add 2 c.c. of HCl; then repeat the experiment, using 2 c.c. of H_2SO_4 instead of ammonium carbonate.

B. *Chemical and physical properties compared.*—In the determination of the chemical properties of a substance it is necessary to observe it during, or subsequent to, some process in which its character is permanently modified. The physical properties of a substance, on the other hand, may be determined without any permanent modification of it. Bodies which are similar in chemical properties may be physically unlike, and vice versa.

1. Mix together, as thoroughly as possible in a mortar, 0.2 gm. of fine iron filings, and 1 gm. of sulphur, examine the mixture with the naked eye and with the lens, and then draw a magnet through a portion of it; finally, heat the rest of the mixture strongly in a matrass, and when cold, powder it and examine as before with lens and magnet.
2. Compare the texture and general appearance of common cotton and gun cotton; then apply a flame successively to small tufts of each.
3. Compare acetic acid, $\text{HC}_2\text{H}_3\text{O}_2$, and ether, $(\text{C}_2\text{H}_5)_2\text{O}$, as to appearance, odor and taste; then put a few drops of each into separate wide-mouthed bottles and apply a lighted match to the mouth of each bottle.
4. Compare the metals sodium and magnesium, as follows :
 - a. By exposing small portions, freshly cut or scraped, to the air.
 - b. By dropping a granule of each into an evaporator containing 5 c.c. of water.
 - c. By treating in the same manner with sodium hydrate.
 - d. By treating in the same manner with HCl.
 - e. By holding a granule of each, with the pincettes, in the lamp flame.
5. Compare carbon dioxide, CO_2 , and oxygen, as follows :
 - a. Fill a large test tube with each gas by downward displacement and plunge a lighted splinter into the mouth of each tube.
 - b. Fill small tubes with each gas as before, pour in 2 c.c. of sodium hydrate, shake the tubes while closed with the thumb, invert them, and open them with their mouths under water for a moment, close them again and after reversing them test the gas in each tube with a lighted splinter.
 - c. Repeat experiment b with each gas using an ammoniacal solution of cuprous chloride instead of sodium hydrate.

C. Evidences of chemical action.—The proof that chemical action takes place between bodies, when

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they are brought together, may consist in the occurrence of one or more of the following changes:

a. A change in temperature, usually elevation.
b. A change in the state of aggregation, consisting in the conversion of a solid into a liquid, or a liquid into a gas, or vice versa. This result is not, however, to be taken as evidence of chemical action, unless accompanied by other phenomena not produced by simple heating or cooling of the substances separately.

c. The production of a galvanic current.
d. The formation of a new substance possessing physical or chemical properties, or both, differing from those of the original substances.

1. Pour 1 c.c. of H_2SO_4 over 2 c. c. of potassium hydrate, while the lower end of the tube is held between the thumb and finger.
2. Mix intimately 1 gm. of powdered potassium chlorate, and 1 gm. of dry powdered sugar, on paper, with a spatula, put the mixture on a piece of tin plate, and touch it with a glass rod previously dipped in H_2SO_4 .
3. Pour 2 c.c. of ammonium hydrate into a test tube containing 2. c.c. of ferrous sulphate.
4. Mix together 2 c.c. of sodium hydrate and 2 c.c. of ammonium chloride, observe the odor, and plunge red litmus paper into the mouth of the tube; then apply heat, and repeat the tests.
5. Add 1 c.c. of potassium iodide to 1 c.c. of mercuric chloride.
6. Add 1 c.c. of HCl to 3 c.c. of cupric sulphate.
7. Repeat the experiment, using ammonium hydrate instead of HCl .

8. Dissolve 0.5 gm. of oxalic acid in 5 c. c. of water, add 1 c. c. of H_2SO_4 , and, finally, a drop of potassium permanganate, and heat gently. Compare the result with that obtained when the same quantity of permanganate is added to a quantity of pure water equal to that of the liquid used before.

9. Repeat the experiment, using potassium dichromate 1 gm. instead of the permanganate, and heat the mixture five minutes.

10. Add 3 c.c. of H_2SO_4 to a granule of zinc in a small test tube, and after two or three minutes apply a lighted match to the mouth of the tube.

11. Put a granule of phosphorus on a small flat cork, touch it with a heated wire, and invert over it a small wide-mouthed jar.

12. Fit a test tube with a small flat cork, pierce in it two parallel slits with a penknife, and insert in one slit a slip of copper foil 0.5 cm. by 6 cm., and in the other a slip of sheet zinc of the same size. Insert in each of the slits an end of a piece of copper wire 10-15 cm. long, so that one wire shall be in contact with each piece of foil. Fill the test tube with H_2SO_4 (1 part acid to 12 of water), insert the cork so that the slips of foil shall be immersed in the acid, and then observe the effect upon the metal, first when the free ends of the wires are not in contact, and afterwards on bringing them together; finally, bring both wires in contact with the tip of the tongue.

CHAPTER II.

Change in state of aggregation by heat alone.—Solution in water.—Solution in other liquids.—One liquid may diminish the solvent power of another.—Fineness of division facilitates solution.

A. Change in the state of aggregation by heat alone.—It is necessary in the course of many chemical operations to bring about a change in the state of aggregation of a body. This may be effected by the action of heat alone. The density of a substance is always changed, usually diminished, when it is heated, and at the same time the mobility of its particles is increased. Solids are fused, *i. e.*, converted into liquids, and liquids are volatilized or converted into vapors. The withdrawal of heat produces corresponding changes in the opposite direction.

FUSION, VAPORIZATION, SOLUTION. 7

1. Drop several granules of phosphorus into an evaporator containing 2 c.c. of warm water, then pour in cold water, allowing the dish to overflow till all the warm water is displaced.
2. Put 1 gm. of paraffine into a dry test tube and immerse the lower end of the tube in boiling water.
3. Heat 2 gms. of sulphur in a dry test tube, raising the temperature to a somewhat high degree, and then allow the tube to cool.
4. Heat 1 gm. of ammonium chloride in a dry test tube.
5. Heat a drop of mercury in a matrass 20 cm. in length.

B. Solution in water.—A similar increased mobility of the particles may be conferred upon solids by the action of liquids, or upon dense liquids by the action of lighter ones. The process is called *solution*, and the liquid employed, the *solvent*.

An acquaintance with the behavior of substances generally, as regards their solubility in various liquids, is of the greatest importance in the study of chemistry; especially important is the solubility of salts and other substances in water, as a means of distinguishing them from one another, or as affecting the methods of manipulating them in the laboratory or in the arts.

1. Compare the solubility, in cold and in hot water, of ammonium chloride, sodium chloride, alum, calcium carbonate (marble), lead chloride, barium sulphate, barium chloride, borax, sulphur, iodine, sugar, and oxalic acid. In each case, except that of iodine, of which only a granule is used, put .5 gm. of the substance into a large test tube, pour over it 5 c.c. of cold water, mix thoroughly by shaking, and observe the solubility as indi-

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cated by the quantity of the solid that disappears; then, if the substance is not all dissolved, heat the same mixture to boiling; if all of the substance disappears, add 1 gm. more, and continue the alternate treatment till a portion remains undissolved, with care to add a little water from time to time to replace what has boiled away; thus compare the solubility in hot water with that in cold. Finally, set the tube aside till its contents become cool, and observe any further change.

C. The use of solvents other than water.—By the use of other solvents we may become acquainted with still other important relations of substances to each other, with reference to their solubility. In the case of mineral substances, mineral solvents, such as water, HCl, H₂SO₄ and HNO₃, have more general application, while for what are commonly called *organic* substances, organic solvents, such as alcohol, C₂H₅HO; chloroform, CHCl₃; benzole, C₆H₆; ether, (C₂H₅)₂O, etc., are more useful.

1. Compare, in the manner described above, the solubility of bone ash (calcium phosphate) in water, HCl, and H₂SO₄.
2. Compare the solubility of potassium nitrate, potassium sulphate, ammonium nitrate, ammonium chloride, and calcium chloride in ordinary alcohol.
3. Put a granule of iodine into 2 c.c. of alcohol, cork the tube and shake it vigorously.
4. Perform a similar experiment with sulphur instead of iodine.
5. Put a granule of iodine into 1 c.c. of carbon disulphide, and shake the mixture strongly.
6. Perform a similar experiment, using roll sulphur instead of iodine.
7. Put together a drop of mercury and a small strip of zinc

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foil, adding a drop of H_2SO_4 to clean the surfaces of the metals and insure direct contact, and let stand several hours.

8. Repeat the experiment, using lead foil instead of zinc, and cleansing the foil with a knife, instead of H_2SO_4 .

D. *One liquid may diminish the solvent power of another.*—When to a solution of a substance in one liquid another liquid is added in which the substance is insoluble, the latter is deposited in proportion to the quantity of the new liquid introduced.

1. To 2 c.c. of lead nitrate (conc. sol.) add 1 c. c. of HNO_3 .
2. Repeat the experiment, using barium nitrate instead of lead nitrate.
3. To 2 c.c. of H_2SO_4 add, cautiously and with constant stirring, 6 c.c. of water. Commercial sulphuric acid contains lead sulphate in solution, as an impurity.
4. To 2 c.c. of sodium sulphate add 1 c.c. of alcohol.
5. Repeat the experiment, using calcium hydrate (lime water) instead of sodium sulphate.
6. To 1 c.c. of tincture of iodine add 3 c.c. of water.
7. Dissolve 1 drop of oil of turpentine in 5 c.c. of alcohol and then add water.

E. *Fineness of division facilitates solution.*

1. Rub 1 gm. of alum to a fine powder in a mortar and treat it with 5 c.c. of water, shaking constantly till the solution is complete; then treat a single crystal of alum, of about the same weight, with water, shaking as before till the salt is dissolved.

F. *Agitation favors solution.*—The process of solution is hastened by continually bringing a fresh

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portion of the solvent in contact with the substance to be dissolved.

1. Put together 1 gm. of powdered cupric sulphate and 4 c. c. of water, allow the mixture to stand five minutes undisturbed, and then shake it vigorously.
2. Suspend a crystal of cupric sulphate, weighing about 1 gm., just below the surface of the water in a wide test tube filled to the brim, and observe the liquid about the crystal.

CHAPTER III.

Limit of solubility.—Saturated solutions.—Separation of the dissolved substance by neutralization of the solvent.—Testing the solubility of a substance.—Heat disappears in the course of solution.—Supersaturated solutions.—A saturated solution of one salt may take other salts into solution.

A. Limit of solubility.—Saturated solutions.—For every liquid used as a solvent there is a certain limit to the proportion of a substance that it can take into solution. This limit is always the same for the same substance and the same temperature, and it is nearly always higher for the same substance at higher temperatures, although, in exceptional cases, cold water dissolves more of a substance than hot. A solution containing as much of a substance as the solvent is capable of holding in solution at any given

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temperature is said to be a *saturated solution*. If such a solution is cooled, or in exceptional cases, warmed, or if a portion of the solvent is removed in any way, a corresponding portion of the substance will be deposited.

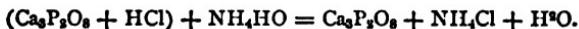
1. Heat together 5 gms. of alum and 4 c. c. of water, till the solution is complete, and then allow the liquid to cool.
2. Boil together 0.5 gms. of lead chloride and 4 c. c. of water and allow the solution to cool completely.
3. Boil together 0.5 gms. of lead iodide and 5 c. c. of water and allow the liquid to cool completely.
4. To 3 c. c. of water add potassium nitrate, in small portions at a time, shaking the mixture after each addition till a part remains undissolved; then heat the liquid.
5. Add finely powdered sodium chloride to 5 c. c. of water, with constant stirring, till a portion remains undissolved; then heat the solution to boiling, with care to replace the water evaporated, and observe the effect upon the quantity of the undissolved portion.
6. Heat 3 c. c. of calcium hydrate to boiling.
7. To 10 c. c. of water, heated to boiling in a small flask, add 20 gms. of potassium nitrate, and shake the mixture strongly, keeping the liquid hot while solution is taking place; pour half of the solution thus obtained into a small evaporator and keep it boiling gently for ten minutes, or until a part of the water has evaporated. Allow the other half to cool in the flask.

B. *Separation of the dissolved substance by neutralization of the solvent.*—A solid may be separated from solution by the addition of a liquid which combines with the solvent.

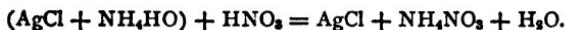
SOLUTION.

I3

1. Dissolve 0.5 gm. of bone ash in 5 c.c. of HCl and add to the solution 10 c.c. of ammonium hydrate.



2. Add a drop of silver nitrate to 3 c.c. of HCl, and then add ammonium hydrate, with constant stirring, till the white precipitate redissolves; finally, add HNO₃ as long as any change appears.



C. Testing the solubility of a substance.—It is important in some cases to know whether a given solid is at all soluble in a given liquid. This may be ascertained by evaporating slowly to dryness, on a slip of glass or platinum, a drop of the liquid with which the solid has been heated, filtered or decanted off. A rough estimate as to the degree of solubility of the substance may also be based upon the amount of residue left on the slip.

1. Heat together 1 gm. of borax and 5 c.c. of water, then filter the liquid, and, after bringing a drop of it upon a slip of clean platinum foil by means of a glass rod, heat the foil gently in the lamp flame noting the quantity of dry residue.

2. Repeat the experiment, using 1 gm. of calcium sulphate, instead of borax.

3. Repeat again, using clean sand instead of borax, but decant the liquid instead of filtering.

D. Heat disappears in the course of solution.—During the solution of a substance a certain quanti-

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ty of heat is taken up or made latent in effecting the change of condition. When a high temperature is required for solution this loss of heat must be continually made up. The action of the so-called "freezing mixtures" depends upon this disappearance of heat and its abstraction from surrounding bodies.

1. Bring 10 c.c. of water to boiling, remove the tube from the lamp, add 5 gms. of potassium nitrate, shake the mixture till the salt is entirely dissolved, and, by means of a chemical thermometer plunged into the liquid, note the change of temperature. Then test the temperature of 10 c. c. of *cold* water, add 2 gms. of potassium nitrate, shake up thoroughly and *quickly*, and again take the temperature.
2. Shake up 3 gms. of ammonium chloride in 5 c. c. of cold water and note the change of temperature as before.
3. Mix together, in a mortar, 3 gms. of ammonium chloride and 5 gms. of powdered ice, and note the change of temperature.
4. Mix together in a mortar 3 gms. of freshly powdered crystals of sodium sulphate, and 5 c. c. of **HCl**.

E. Supersaturated solutions.—Under certain conditions, bodies more soluble in hot than in cold water may refuse to separate from a saturated solution on cooling. Such solutions are said to be *supersaturated*. The phenomenon occurs especially in the case of salts which form definite combinations with water. Under free exposure to air, or mechanical agitation, or other conditions, the solution returns in

time to its normal state and deposits the excess of solid in accordance with the law previously stated.

1. Boil about 50 c.c. of water in an evaporator and add, with constant stirring, dry sodium sulphate as long as it will dissolve; when thoroughly saturated, filter the hot solution rapidly into large test tubes, partly filling each. Close the mouth of one tube with a rubber stopper, and leave another entirely uncovered. Allow the tubes to cool without the least disturbance of their contents, and when quite cool, remove the stopper of the closed one, and, if no change takes place, drop in a small crystal of the sulphate.

F. A saturated solution of one salt may take other salts into solution.—A solution saturated with one salt is capable of taking up an additional and definite quantity of another salt.

1. Add potassium nitrate, in small portions at a time, to 5 c.c. of boiling water until a portion remains undissolved, pour the clear solution into another tube and slowly add to it, while boiling, small portions of ammonium chloride; decant the clear liquid off again and while boiling it slowly add crystals of magnesium sulphate. Replace the water as it is boiled away.

2. Repeat the experiment without boiling in any case, but closing the tube and shaking it vigorously after each new portion of the substance to be dissolved has been added.

CHAPTER IV.

Deliquescence.—Solution of liquids in liquids.—Miscibility of liquids.—Removal, by solution, of a substance suspended in a liquid.—Absorption of gases by liquids.—Colored test solutions.—Physical and chemical solution.—The new substance produced, in chemical solution, must be soluble.—Action of natural waters on metals.

A. Deliquescence.—The attraction between a solid and a liquid, in virtue of which solution takes place, is in some cases so strong that the solid if simply left exposed to an ordinarily moist atmosphere will attract enough water from that source for its solution. This is called *deliquescence*.

1. Leave 1 gm. of potassium hydrate, and the same quantity of calcium chloride, exposed to the air for an hour on separate watch glasses.
2. Evaporate 2 c.c. of cupric chloride in a watch glass, on the sand bath, to dryness, then breathe several times upon the residue.

B. Solution of liquids in liquids.—The action of one liquid upon another is in some cases analogous to a process of solution, and different liquids exhibit with respect to others definite degrees of solubility.

1. Add 1 c.c. of oil of turpentine to 10 c.c. of alcohol and shake the mixture vigorously till the liquid has become clear; then add water.
2. Half fill a test tube with water, pour in a sufficient quantity of ether to produce a visible layer upon its surface, observe the thickness of this layer, shake the mixture vigorously, and, still closing the mouth of the tube with the thumb, allow the liquid to become clear; finally note again the thickness of the layer of ether.
3. Repeat the experiment using 5 c.c. of ether and a single drop of water.
4. Put several drops of any fatty oil in 5 c.c. of water, another portion of oil in a like quantity of alcohol and a third in ether; shake the mixtures vigorously and set them aside for a few minutes.

C. Miscibility of liquids.—Many liquids, however, may be mixed with other liquids in all proportions and at all temperatures, exhibiting neither condensation, change of temperature, nor any of the phenomena commonly regarded as evidences of solution. In such cases it is said that the liquids are *miscible* with each other.

1. Mix together 1 c. c. of ether and one of oil of turpentine; then add 3 c. c. of ether; *use a dry test tube*.
2. Put together 5 c. c. of water and 1 c. c. of glycerine, *shake* the tube, add 1 c. c. more of glycerine and shake again.

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D. Removal, by solution, of a substance suspended in a liquid.—A finely divided solid or liquid, suspended in a liquid in which it is insoluble, may be removed by the action of a second liquid which dissolves the suspended substance, while it does not mix with the first liquid.

1. Shake up a drop of olive oil in a test tube half full of water, then add 2 c.c. of ether, shake again vigorously, and allow the tube to stand for ten minutes; then dip a slip of dry, unsized printing paper into the upper layer of the liquid in the tube, and expose the paper to the air for a few minutes. Compare the final result obtained with those produced when a drop of the oil is put on another slip of paper, and a drop of ether on still another.

2. To one c.c. of tincture of iodine add 10 c.c. of water, shake the mixture strongly, and when the solid particles first separated have settled to the bottom of the tube, pour off the water and again add a like quantity of water to the residue in the tube, shake the tube, add 0.5 c.c. of carbon disulphide, shake the mixture again for a short time, and allow it to stand for ten minutes before noting the result.

E. Absorption of gases by liquids.—Many gases are absorbed by liquids in a manner somewhat analogous to the solution of solids in liquids. Condensation or diminution of the volume of the substance dissolved, is, in this case, an important distinction between the two processes.

1. Immerse the lower end of a test tube containing 1 c.c. of ammonium hydrate in hot water, and after a minute close the mouth of the tube with the thumb, invert it in a vessel of cold water and remove the thumb.

2. Repeat the experiment, using **HCl** and *boiling* water, instead of ammonium hydrate and merely hot water.

3. Put 5 c.c. of oxygen in a large test tube inverted over water and let it stand a minute. Repeat the experiment with a tube containing 10 c.c. of nitric oxide; finally, pour the contents of the second tube upwards through the water into the first.



F. Colored test solutions.—All chemical substances may be classified as acids, bases, or neutral bodies. When a substance is soluble it is possible to determine the class to which it belongs by bringing its solution in contact with certain vegetable coloring matters, such as litmus. Acids turn blue litmus red, bases turn red litmus blue, while neutral bodies have no effect upon either color.

1. Put a piece of blue and one of red litmus paper into pure water.

2. Add a drop of HCl to the same water.

3. Add potassium hydrate, drop by drop, to the same solution, until a change occurs.

4. Put a small quantity of clean sand into an evaporator, add 10 c.c. of water and drop in pieces of red and of blue litmus paper. Sand is moderately pure silicic anhydride, SiO_2 .

5. In the same manner test the action of these neutral, acid and basic substances on infusion of red cabbage.

6. In the same manner test the action of acids, bases and neutral bodies on tincture of turmeric.

G. Physical and Chemical solution.—The phenomena of solution may be divided into two classes: physical solution and chemical solution.

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In the case of physical solution the substance dissolved is not chemically changed, while in the case of chemical solution it is chemically altered.

Physical solution.—

1. As one of many illustrations of physical solution that may suggest themselves, dissolve 2 gms. of common salt in 5 c.c. of water and compare the taste of the solution with that of the original substance; then evaporate the solution to dryness with constant stirring, and compare the solid residue obtained with the original substance.

Chemical solution.—

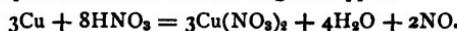
2. Dissolve 1 gm. of potassium carbonate in 5 c.c. of HNO_3 , evaporate the solution to dryness, and compare the product with the original substance with respect to its taste, and its behavior with HNO_3 .



3. Perform a similar experiment with 1 gm. of magnesium carbonate and HCl.



4. Heat cautiously 5 c.c. of HNO_3 and 1 gm. of copper foil; when the solution is complete, evaporate the liquid to dryness and compare the residue with the original copper.



H. The new substance produced must be soluble.—

In order that this *chemical* solution shall take place, however, it is essential that the new compound formed be soluble in the liquid in which it is produced.

1. To 2 c. c. of alcohol, put into a dry test tube, add 0.5 c. c. of **HCl**, mix by shaking, and drop a small lump of fused potas-

SOLUTION.

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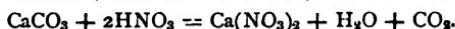
sium carbonate into the mixture; after observing the effect, drop into a similar liquid in another test tube a small fragment of marble.

2. Repeat experiment 1, using water instead of alcohol.



3. Test the solubility of potassium chloride, KCl, and calcium chloride, CaCl₂, in alcohol and in water.

4. Repeat experiments 1 and 2, using **HNO₃** instead of **HCl**.



5. Test the solubility of potassium nitrate, KNO₃, and of calcium nitrate, Ca(NO₃)₂, in alcohol and in water.

6. Pour 1 c.c. of **HNO₃** over 1 gm. of barium carbonate, observe the action for a moment, then add 2 c.c. of water, mix by shaking and observe the result; when all action appears to have ceased, repeat the addition of water, and so on *ad libitum*.



7. Test the solubility of barium nitrate, Ba(NO₃)₂, in **HNO₃** and in water.

8. In a clean test tube dissolve .5 gm. of tartaric acid in 5 c.c. of alcohol and drop a granule of potassium carbonate into the solution.

9. Repeat the experiment, using water instead of alcohol, to dissolve the tartaric acid.

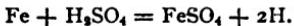


10. Test the solubility of potassium bitartrate, KHC₄H₄O₆, in alcohol and in water.

11. Heat cautiously 1 gm. of lead in 3 c.c. of **H₂SO₄**; then repeat the experiment, using H₂SO₄ instead of **H₂SO₄**. Finally, test the solubility of lead sulphate in **H₂SO₄** and in H₂SO₄.

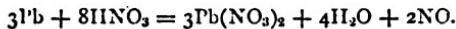


12. Repeat experiment 11, using iron filings instead of lead,



13. Heat 1 gm. of lead with 3 c.c. of **HNO₃**, and, after a minute, add 10 c.c. of water and heat again.

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14. Test the solubility of lead nitrate in ~~HNO₃~~ and in water.

I. Action of natural waters on metals.—The action of water upon mineral matters by simple solution is important as furnishing an explanation of the composition of natural waters of springs, rivers, etc.; but its action as a chemical solvent in virtue of these substances held in solution is hardly less important. Pure water exerts no action upon metallic lead, while water containing certain gases in solution does act rapidly upon the metal; even distilled water, unless specially freed from dissolved gases, acts very readily in this manner. While some of the salts that may be contained in natural waters favor this solvent action, others oppose it by the immediate formation of an insoluble coating upon the leaden surface, thus preventing the contamination of the water by the lead.

1. Put 1 gm. of clean lead, in fine shavings, into 10 c.c. of water, and, after twenty-four hours, decant the clear liquid into a second test tube and pass a current of sulphuretted hydrogen through it for two minutes, and examine the contents of the tube by looking through it lengthwise.

2. Provide five other tubes with like quantities of lead and distilled water, number the tubes, and to the contents of number 1 add a drop of sodium chloride, to number 2 a drop of potassium nitrate, through the water of number 3 pass a current of carbon dioxide, to number 4 add a drop of calcium sulphate, and to number 5 sodium sulphate. After twenty-four hours decant the water in each case into a clean tube, and treat as before with sulphuretted hydrogen.

CHAPTER V.

Substances in solidifying assume definite forms.—

Dimorphism.—Water of crystallization.—Sympathetic inks.—Amorphous substances.

A. Substances in solidifying assume definite forms.

—Solid bodies on cooling from a state of fusion or vaporization, or in separating from solution by any of the modes already described, tend in general to assume certain definite and symmetrical forms called *crystals*. When this return to the solid condition proceeds slowly, the resulting crystals are larger and more perfect than when it proceeds rapidly.

An important means of distinguishing one substance from another, and of identifying any given substance, is found in the constancy of crystalline form which it exhibits among the great variety of forms presented by different substances.

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1. Examine with a lens freshly broken surfaces of cast iron, of zinc (spelter), and of metallic bismuth.
2. Heat 10 gms. of sulphur carefully in a dry test tube till it is entirely fused to a thin liquid, let it cool slowly and in quiet till a crust is just formed over the surface, pierce this crust with a glass rod and quickly pour out the liquid sulphur underneath it; then break the tube, and carefully break open the lump of sulphur. Reserve this product.
3. Heat 0.5 gm. of arsenious oxide in a dry test tube, and examine the product with a lens.
4. Examine with the lens portions of sugar, oxalic acid, potassium nitrate, cupric sulphate, and alum, from the reagent bottles.
5. Evaporate *slowly* in separate watch glasses laid on the sand bath 2 c.c. each of potassium chlorate, potassium nitrate, potassium dichromate, sodium phosphate, mercuric chloride, and cupric chloride.
6. Boil 0.5 gm. of lead chloride in 3 c.c. of water, pour off the clear solution and allow it to cool.
7. Repeat the experiment with mercuric chloride.
8. Add 1 c.c. of HNO_3 to 3 c.c. of barium chloride.
9. Put 3 c.c. of tartaric acid and 5 c.c. of potassium nitrate together, shake the mixture strongly and examine the product with a lens.

B. Dimorphism.—While the crystalline form of a substance is generally constant, certain substances may present two, or even more, widely different forms belonging to different systems of crystallization. Each of these forms depends, however, for its occurrence upon certain physical or chemical conditions, and is always reproduced under these given conditions.

1. Compare the crystals obtained by fusing sulphur and allow-

ing it to cool (experiment 2, A) with those obtained when a solution of 0.5 gm. of sulphur in 2 c.c. of carbon disulphide is exposed to the air for ten minutes in a strong draught.

C. Water of crystallization.—Water is often incorporated in the crystal of a salt and is necessary to its formation (water of crystallization). Sometimes this water will escape at common temperatures, in the ordinary way, or in an artificially dried atmosphere, and the phenomenon is called *efflorescence*; in other cases heat is required to expel it; or, lastly, it may be given off when, during the action of one crystallized substance upon another, a new compound is formed requiring less or no water of crystallization.

1. Leave a clear, transparent crystal of sodium sulphate or Glauber's salt exposed to the air for half an hour.
2. Heat a clear, transparent crystal of sodium carbonate gently on platinum foil.
3. Repeat the experiment, using borax instead of sodium carbonate.
4. Put a clean, bright crystal of alum in the desiccator and after fifteen or twenty hours compare its appearance with that of alum kept in ordinary air.
5. Mix 2 gms. of plaster of Paris with water to a stiff paste and let it stand undisturbed until quite dry; then heat a portion of the dry mass in a matress; finally, heat fresh plaster of Paris in the same way.
6. Heat 5 gms. of finely powdered cupric sulphate carefully in an evaporator with constant stirring, till the residue is quite white; when cold, add to it 2 c.c. of water, slowly and with constant stirring.

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7. Rub together in a mortar 1 gm. of alum, $K_2SO_4 \cdot Al_2(SO_4)_3 + 24H_2O$, and 1 gm. of lead acetate, $Pb(C_8H_6O_2)_2$.

D. Sympathetic inks.—The difference in color between the anhydrous and hydrated condition of the crystal, together with the readiness with which the water of crystallization can sometimes be taken up again from moist air, after having been expelled by heat, is occasionally utilized in the so-called *sympathetic inks*.

1. Write on paper with a small splinter previously dipped in a dilute solution of cobalt chloride, $CoCl_3$, carefully dry and warm the paper, and afterwards let it cool again while exposed to the air.
2. Repeat the experiment using a dilute solution of cupric chloride, instead of cobalt chloride, and dry the paper carefully over the lamp at a moderate heat; then breathe repeatedly on the paper.

E. Amorphous substances.—While most substances in returning to the solid condition from a state of fusion or solution tend to assume some crystalline appearance, there are many, especially among the so-called *organic compounds*, which never exhibit the least approach to crystalline structure.

1. To 5 c.c. of sodium silicate add 2 c.c. of HCl and examine the product with a lens.

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2. Heat 2 gms. of sulphur in a dry test tube to boiling and pour separate portions of the fused mass into vessels of cold water at intervals of half a minute.
3. Examine gum arabic and common animal glue for traces of crystalline structure.
4. Heat 5 gms. of granulated, or loaf sugar with 3 c.c. of water, in an evaporator, till perfectly transparent; then allow it to cool and compare the product with the original substance.

CHAPTER VI.

Forces opposing chemical action.—Chemical action takes place only at insensible distances.—The nascent state.

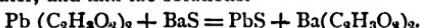
A. Forces opposing chemical action.—When elements or compounds react on one another to form new and homogeneous substances, various forces have to be overcome. If one or more of the reacting substances is a solid, while the product is a liquid or gas, the force of cohesion in the solid must be overcome ; if from liquids gases are formed, there is still a certain amount of cohesive force opposing the change ; if from gases a liquid or solid is to be formed, the repulsive force that keeps the particles of gases asunder has to be mastered. In all cases the chemical force which binds together the atoms in the original substance has to be overcome.

Whatever opposes these forces may facilitate

chemical action. Heat increases repulsive forces, counteracting in a measure the cohesive forces; solution of solids is a change in the direction of the neutralization of the cohesive forces; absorption of gases by liquids counteracts their elastic force; if this elasticity of the gases be overcome by other means, as by compression, the same chemical results may in some cases be obtained without the intervention of a liquid.

Chemical action takes place more readily between bodies in proportion to the mobility of their particles; this freedom of motion is greater in gases and liquids than in solids.

1. Rub together in a mortar 1 gm. of dry barium sulphide and 1 gm. of lead acetate, then dissolve like quantities of each in 5 c.c. of water, and mix the solutions.



2. Rub together, in a mortar, 1 gm. of cupric sulphate, and 1 gm. of sodium carbonate; examine the powder with a lens, then mix 1 c.c. of solutions of each of the same substances.

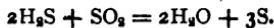
3. Rub together, in a mortar, 1 gm. of oxalic acid and 1 gm. of anhydrous sodium carbonate, and examine the product; then pour water upon the mixture.



4. Bring together, in an ignition tube, by means of the Y tube, a moderate current of dry sulphuretted hydrogen from the generator, and a current of sulphurous oxide, SO_2 , prepared in a test tube in the usual manner, and dried by carrying it through a U tube of the drying battery; after the mixed gases have passed through the ignition tube for half a minute, observe the result,

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detach the tube, rinse it with water so that its interior will be wet, and again pass the mixed gases through it.



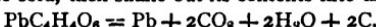
5. Put into a test tube 6 gms. of an intimate mixture of equal parts of well dried and slaked lime, and powdered ammonium chloride, plunge the tube into a dish of boiling water, and, by means of the adapter, convey the current of ammonia gas through an ignition tube containing a spiral of copper foil; continue the current for a minute or two after the ammonia begins to issue from the free end of the tube, and then observe the condition of the foil; finally, detach the ignition tube, throw a jet of water through it from the washing bottle so that the foil will be well moistened, and again conduct ammonia through it.

B. Chemical action takes place only at insensible distances.—This condition is fulfilled in the case of mixtures of substances in the gaseous or liquid form. It may also be fulfilled when a finely divided solid is brought in contact with a liquid or a gas, or when solids in a fine powder are intimately mixed or strongly pressed together.

1. Hold a test tube containing 1 c.c. of cupric sulphate in an inclined position and pour slowly down the side of the tube 2 c.c. of ammonium hydrate, so that it will form a layer over the cupric sulphate; after noting the result, mix the solutions by agitation.

2. Repeat the experiment, using ferric chloride instead of cupric sulphate.

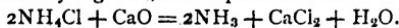
3. Heat 0.5 gm. of dry lead tartrate in a narrow matrass 10 cm. in length until fumes cease to be evolved. Allow the tube to become quite cold, then shake out its contents into the air.



4. Put together in a mortar 1 gm. of ammonium chloride and

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1 gm. of lime, examine the mixture, noting the odor and action on red litmus paper held directly over it; finally, grind the substances intimately together, and repeat the tests.



5. Put a granule of sulphur and one of potassium chlorate into a mortar and rub them together, pressing strongly upon the pestle.

This experiment is dangerous if any quantities larger than those specified are put into the mortar together. The mortar should be perfectly dry.

C. The nascent state.—Substances in the nascent state, *i. e.*, in the condition of being set free from some compound, exhibit often, if not always, greater activity than after they have passed through this condition.

1. Take two portions of 1 c.c. each of ferric chloride, add to each 4-5 c.c. of water, 2 drops of cupric sulphate and 2 c.c. of H_2SO_4 , noting whether any effect is produced on the addition of each of these substances, then :

a. Through one of these solutions pass a slow current of hydrogen made in the usual way, and after 15-20 minutes add a drop of potassium sulphocyanate.

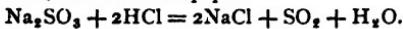
b. Cause hydrogen to be liberated in the other portion by adding to it 1 gm. of zinc foil, and after rapid evolution of hydrogen for 15-20 minutes pour off some of the liquid from the zinc and test it with potassium sulphocyanate immediately.

Finally test solutions of ferric and ferrous salts with potassium sulphocyanate.

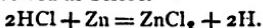
2. Repeat experiment 1 using potassium dichromate instead of ferric chloride and HCl instead of H_2SO_4 , and for the final test barium chloride instead of potassium sulphocyanate. Then apply the barium chloride test to potassium dichromate and chrome alum.

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3. *a.* Put 2 c.c. of HCl with 3 c.c. of sodium sulphite, heat gently, and test the gas evolved with a lighted match and by its odor, and with lead paper.



- b.* Pour 2 c.c. of HCl upon 1 gm. of metallic zinc and test the gas evolved as before.



- c.* Put together, in a single test tube, fresh portions of the materials used in each of the foregoing experiments, and test the gas evolved, as in the preceding cases.



- d.* By means of a Y tube bring hydrogen and sulphurous oxide together, and test the escaping mixture as above.

CHAPTER VII.

Chemical change produced by light.—Heat and chemical action.

A. *Chemical change produced by light.*—Chemical change may take place under the influence of light alone, and of light from various sources.

1. Dip a piece of filter paper first into a dish containing 5 c.c. of silver nitrate, then into one containing a like quantity of sodium chloride, and, finally, expose it to direct sunlight for two minutes.
2. Dip two pieces of salted photographic paper into an iodized solution of silver nitrate; put each between small plates of window glass, then lay a coin or any solid, opaque object on each plate, and expose one to direct sunlight, the other, in a dark closet, to the light of burning magnesium.
3. Repeat the experiments in a dark closet, using, in one case, the light of a burning mixture of nitric oxide and carbon disulphide vapor, made by shaking a few drops of liquid disulphide in a closed jar of nitric oxide, and applying a lighted match to the jar as soon as it is opened; and, in the other case, using the light obtained by dropping fragments of sulphur into a crucible containing potassium nitrate in a state of fusion.

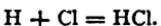
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4. Dip a piece of filter paper into a saturated solution of potassium dichromate, lay a leaf on it, press the leaf under a plate of glass and expose the whole to direct sunlight for half an hour.

5. Add 1 c. c. of oxalic acid to 3 c. c. of ferric chloride, and a drop of potassium ferricyanide, expose the mixture to direct sunlight for fifteen minutes, and observe the effect from time to time during the exposure; then test the gas in the upper part of the tube by means of a drop of calcium hydrate in the looped tube. Carbon dioxide gives a white precipitate with calcium hydrate. Treat separate portions of 3 c. c. each of oxalic acid and ferric chloride in the same manner.



6. Put 3 volumes of hydrogen and 1 of chlorine, roughly estimated by measurement in the tube itself, in a large test tube inverted over a strong solution of common salt, introduce a piece of blue litmus paper through the water into the tube, and note the effect of the gaseous mixture on it. Then expose the tube to direct sunlight for five minutes, and test again with blue litmus paper.



7. Fill a flask holding about a quarter of a litre with water, and saturate the water with carbon dioxide gas conducted through a tube leading to the bottom of the flask; fill a large test tube with the water, pour the rest into a dish, invert the tube in the dish, and introduce a twig bearing fresh young leaves into the tube. Expose the whole to direct sunlight for an hour or two, then close the mouth of the tube with the thumb, reverse it, and, with a glowing match, test any gas that may have accumulated in the tube during the exposure.

B. Heat and chemical action.—A most intimate relation exists between heat and chemical action the two most prominent features of which are the elevation of temperature which accompanies the act of chemical combination and the much wider range of chemical action that is possible at high than at low temperatures.

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The application of this principle is so general that only a few experiments need be given here; other experiments throughout the manual will be found to furnish abundant illustration of it.

1. Mix 1 c.c. of strong potassium hydrate solution with 1 c.c. of H_2SO_4 , holding the bottom of the tube between the thumb and finger.



2. Put 1 gm. of zinc in 3 c.c. of sulphuric acid in a test tube held in the same way.

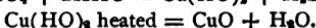


3. Heat 2 gms. of sulphur in a dry test tube till it boils, and then, with the pincettes, hold in the tube a piece of thin copper foil, previously warmed.



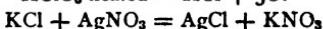
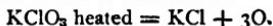
4. Add 3 c.c. of sodium acetate to an equal volume of ferric chloride, and heat to boiling.

5. Add 2 c.c. of potassium hydrate to 4 c.c. of cupric sulphate and heat slowly to boiling.

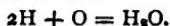


6. Heat 1 gm. of the blue salt, cupric nitrate, in a small dry test tube.

7. Dissolve a few crystals of potassium chlorate in water, and add 1 c.c. of silver nitrate to the solution. Then heat 1 gm. of potassium chlorate in a dry test tube, and hold a lighted match at the mouth of the tube; after a quantity of gas has been evolved, allow the tube to cool, dissolve the residue in water, and add a few drops of silver nitrate to the solution.



8. Conduct oxygen into a test tube inverted over water, till it is one third full, and replace the remainder of the water by hydrogen; remove the tube after closing it with the thumb, heat a glass rod to faint redness, and, removing the thumb, quickly thrust the heated rod into the tube.



CHAPTER VIII

Elements differ from one another.—Elements constant in character.—Allotropism.—Combination of elements with each other.—Union of compounds with each other.—Relative stability of different compounds.

A. Elements differ from one another.—Elementary substances differ from one another in respect to their chemical as well as their physical properties.

1. Compare the gaseous elementary substances hydrogen, oxygen, nitrogen, and chlorine, by filling a test tube with each in turn, plunging a lighted match into the tube, allowing the tube to stand mouth upward for a minute, and then applying the flame again.
2. Compare sodium, iron, iodine, lead, zinc, phosphorus, carbon, and sulphur, as follows, taking only a granule for each test:
 - a. When put separately on the lid of a porcelain crucible and touched with a burning match, and also when heated strongly by a small flame applied under the lid.
 - b. When treated separately in a test tube with H_2SO_4 or HNO_3 , aided by a gentle heat.

B. Elements constant in character.—An important feature in the chemistry of a substance is the constancy of character which it maintains, however diverse may be the methods of preparing it.

1. Prepare oxygen by each of the following methods, and collect the gas in large test tubes over water, by means of the adapter and exit tube :

a. Heat 1 gm. of potassium chlorate strongly in a dry test tube.

b. Heat 0.5 gm. of dry mercuric oxide strongly in a matrass.

c. Heat 1 gm. of manganese dioxide also in a matrass.

d. Prepare two plates of thin platinum foil 4 cm. long and 1 cm. wide, attach each by platinum wires to the copper wires leading from the poles of a galvanic battery of two Bunsen cells; plunge both plates of foil in a dish containing distilled water acidulated with H_2SO_4 , invert in the dish over the plate that is connected with the carbon (positive pole) of the battery a test tube filled with the same acidulated water, and allow the current to pass till the tube is one third filled with gas.

Finally, test each portion of oxygen thus obtained, as follows :

a. By passing a bubble of nitric oxide into each tube while still inverted over water.

b. By plunging a glowing match into each tube after removing it from the water in the usual manner.

2. Prepare metallic copper as follows :

a. By putting a slip of zinc foil into 5 c.c. of cupric sulphate and collecting the spongy mass which adheres to the zinc.

b. By dipping a moistened splinter into powdered cupric nitrate, burning it, and grinding and washing the residue.

c. By the galvanic current. Immerse the two platinum plates connected with the poles of a two-cell Bunsen battery in a dish containing 20 c.c. of cupric sulphate and 10 drops of H_2SO_4 .

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To compare the portions of metallic copper thus obtained, put some of each in separate tubes, boil each with 2 c.c. of HNO_3 , add to each a drop of HCl, and finally, add to each ammonium hydrate, slowly, as long as any change appears to be produced.

3. Prepare hydrogen as follows:

a. By pouring 3 c.c. of H_2SO_4 over 1 gm. of zinc, allowing the gas to escape for a minute or two, then collecting it over water in the usual way.

b. By heating together, in a dry test tube, 0.5 gm. of potassium hydrate and 2 gms. of iron filings, and collecting the gas as before.

c. Repeat experiment 1 d, collecting the gas from the negative (zinc) pole instead of the positive pole.

To compare the three portions of gas thus obtained, hold each tube mouth upwards and quickly test its contents with a lighted match.

C. Allotropism.—In some cases, however, the same elementary substance does appear in forms that differ from one another to a very marked degree, in respect to physical or chemical properties, or both. Substances behaving in this manner are said to occur in *allotropic modifications*.

1. Heat 5 gms. of sulphur in a large dry test tube, shaking it occasionally after it begins to fuse, and noting any change in the degree of fluidity. When the liquid boils, remove it from the lamp, and pour small quantities of the fused sulphur into a vessel of cold water at intervals of a minute, till the mass solidifies in the test tube. Compare the different cold portions of sulphur thus obtained as to their consistency, observing the order in which they were produced.

2. Put a granule of common phosphorus and a bit of red phosphorus, about 4 cm. apart, on a piece of sheet iron, apply a low flame under the iron, and gradually increase the heat to redness.

3. Put a granule of charcoal and one of graphite, side by side, on the platinum foil, and while heating to redness, remove the foil from the flame from time to time to observe any difference in the behavior of the two substances.

4. To 1 gm. of powdered charcoal add 5 drops of H_2SO_4 , heat gently for a minute, and then, after removing the lamp, test the odor of the gas in the upper part of the tube.



Introduce into the tube a small piece of brightly colored, moistened calico, wrapped around the end of a glass rod held in a perforated cork fitting loosely in the mouth of the tube, and leave it for a few minutes.

5. Repeat both experiments, using powdered graphite instead of charcoal.

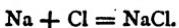
D. Combination of elements with each other.—Elementary substances unite with one another, and with different degrees of energy.

1. Introduce into the bottle gasometer, first, 2 volumes of hydrogen and then 1 volume of oxygen; force a portion of the mixture into a dish of soap suds, *remove the gasometer to a distance*, and apply a lighted match to the mass of bubbles in the dish.

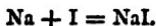
Repeat the experiment, using nitrogen instead of hydrogen.

2. Compare the behavior of sodium in the presence of chlorine, iodine and hydrogen respectively, in the following manner:

a. Fill a large test tube with chlorine, by downward displacement, and then heat a granule of sodium in a deflagrating spoon and plunge it into the gas.



b. Heat a crystal of iodine in a test tube till the tube is filled with the violet vapor, and introduce a granule of sodium as before.

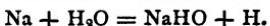


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- c. Fill another tube with dry hydrogen and drop a granule of sodium into the tube, quickly closing the mouth again with the thumb.
3. Put a granule of iodine into an evaporator in contact with a granule of phosphorus previously dried between folds of filter paper.
4. Repeat the experiment, using sulphur instead of phosphorus.
5. Heat a granule of sodium in a dry test tube with a granule of sulphur. Repeat the experiment, using iron instead of sodium.
6. In one cavity blown in the side of an ignition tube put a drop of mercury, in another similar cavity, 3 cm. from the first, put a granule of iodine, and heat both gently, inclining the tube so as to bring the iodine somewhat higher than the mercury.
7. In a dry test tube heat together a granule of iodine and one of antimony.

E. Union of compounds with each other.—Compound substances unite to a large extent with one another, forming new compounds.

1. Put 10 c.c. of distilled water and a bit of blue litmus paper into a small evaporator, and, on a small flat cork floated on the water, put a granule of phosphorus; ignite the phosphorus with a hot wire, and invert over it a small wide-mouthed jar; let the jar remain in that position till the air within it has become clear, then remove it together with the cork, and throw a granule of sodium into the dish.



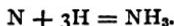
2. a. Put a piece of potassium hydrate, 1 cm. long, in a large mattress, pour over it 3 gms. of fine iron filings, heat the mixture and collect the gas evolved (hydrogen), by means of the adapter and exit tube, in a test tube inverted over water; then test the gas with a lighted match.

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b. Treat in a similar way a mixture of 1 gm. of potassium nitrate, and 3 gms. of iron filings, collect the gas evolved and test it as before with a lighted match.



c. Heat new quantities of the materials used in *a* and *b*, all together, in a large mattrass, leaving the mouth of the tube open, and test the gas evolved with red litmus paper held in the mouth of the tube; test it also by its odor, and by holding the stopper of the **HCl** bottle in the mouth of the tube.

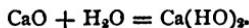


d. By means of the Y tube, conduct into a wide ignition tube a current of hydrogen and one of chlorine, simultaneously, heat the tube to redness, and test the gases issuing from the free end with blue litmus paper, and also by means of the stopper of the ammonium hydrate bottle.



e. Finally, rinse out one test tube with ammonium hydrate and another with **HCl** from the reagent bottles, and bring the mouths of the tubes together.

3. Pour 2 c.c. of water into an evaporator containing 1 gm. of quicklime.



4. Add 1 c.c. of water cautiously to 1 c.c. of **H₂SO₄**, resting the bottom of the tube on the palm of the hand.

F. Relative stability of different compounds.—

While any element will probably unite with any other element, under favorable conditions, the reverse is true, in the main, of compounds. The energy of chemical combination and probably, also, the

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stability of the compounds formed, as a rule, are greater the nearer the combining substances are to the elementary form, being in general greatest between elements, less between compounds of two elements and least between compounds of three or more elements. In the case of exceptions to this rule, at least one of the elements concerned is characterized by its comparative chemical indifference.

1. Put a granule of iodine into a small evaporator, crush it into a coarse powder with the rounded end of a glass rod, and pour over it four times its bulk of ammonium hydrate. After fifteen minutes, decant the liquid, and, with a feather, gently remove the moist solid residue to a flat cork or a block of wood, and set it aside in a safe place to dry. When dry, touch it with the end of a long splinter of wood or a feather. The compound formed here is, in part, nitrogen iodide.

CHAPTER IX.

Constancy in the properties of a compound.—Isomerism.—Original character not always obliterated in combination.

A. Constancy in the properties of a compound.—
The chemical properties of a compound, as in the case of an element, are, in general the same, however diverse may be the methods of preparing it.

1. Prepare carbon dioxide by the following methods:

a. Treat 1 gm. of marble with 2 c.c. of HCl, attach the adapter and exit tube and collect the heavy gas evolved, by downward displacement, in a large test tube. Cork the tube securely and reserve the product.

b. Force a slow stream of oxygen through an ignition tube containing fragments of charcoal heated to redness, and collect the gas evolved as before. Test each product, first with a lighted match, then by pouring 2 c.c. of clear calcium hydrate into the tube and shaking the mixture.

2. Prepare sodium chloride as follows:

a. Over a granule of sodium in an ignition tube, carry a current of chlorine, and heat the tube gently; when the reaction is ended and the tube has been allowed to cool, rinse the contents into an evaporator, and evaporate to complete dryness on the water bath.

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b. Add 2 c.c. of **HCl** to 4 c.c. of sodium hydrate in an evaporator and evaporate to dryness as before.

c. To 5 c.c. of sodium sulphate heated to boiling, add barium chloride in successive small portions, as long as a precipitate is produced, allowing the precipitate to subside after each addition, and *carefully* avoiding any excess of the barium salt; filter out the precipitate and evaporate the filtrate to dryness.



Compare the three portions of sodium chloride thus obtained in respect to their solubility in water and in alcohol, their taste, their crystalline form, and their behavior with H_2SO_4 when heated with it; test for gaseous products in the latter case by odor and test papers.

B. Isomerism.—This term is applied to the property possessed by certain compounds of changing their color, solubility and other physical, or even chemical properties, while preserving their chemical composition. In exceptional cases the same compound may possess different properties, as in the case of allotropism among elements.

The term is also applied, especially in organic chemistry, to substances, not convertible into one another, having the same ultimate chemical composition but different properties.

1. Examine commercial arsenic (arsenious oxide) carefully as to its appearance; then heat a granule of the same substance gently in an ignition tube slightly inclined, and, when the tube is cool, with a lens examine any deposit which may be formed on the walls of the tube.

2. Heat a small quantity of mercuric iodide gently in a dry test tube, and, when cold, rub the product with a glass rod.

C. Original character not always obliterated in combination.—While, as a rule, when one element or compound unites with another, the characteristic properties of each constituent of the new compound disappear, one of the constituents may, in rare cases, still exhibit those characteristic properties, though with a more or less diminished intensity. Abundant illustration of the rule will be found in experiments already performed. The exceptions will be illustrated by the experiments that follow.

1. Put 5 gms. of ammonium nitrate in a large, dry test tube, attach the adapter and exit tube, and collect the gas which is evolved on heating, nitrous oxide, in jars or large test tubes.



Plunge a splinter of charcoal attached to a wire into a jar of nitrous oxide, then withdraw the wire, heat the charcoal till it glows brightly, and again plunge it into the gas, keeping the jar covered except while introducing the wire.

2. Compare the burning of sulphur in oxygen and nitrous oxide as follows: heat the sulphur moderately and immerse it first in one jar, and then in the other; afterwards, heat it till it inflames, and repeat the immersions.

3. To 10 c.c. of water add 1 c.c. of red litmus and 1 c.c. of sodium hydrate; then, by means of the adapter and exit tube, pass through the liquid a stream of hydrochloric acid gas, made by heating together 1 gm. of sodium chloride and 5 c.c. of H_2SO_4 . Repeat the experiment, using, instead of hydrochloric acid gas, a current of carbon dioxide from a mixture of 1 gm. of marble and 5 c.c. of HCl.

Finally, pass some of each gas in turn through 5 c.c. of water faintly colored with blue litmus. Sodium hydrate is a strong base and unites eagerly with all acids.

CHAPTER X.

Combination in definite proportions.—Multiple proportions.—Instability of compounds in higher proportions.

A. Combination in definite proportions.—Elements as well as compounds unite with each other only in definite proportions.

I. *a.* Introduce a lighted match into a test tube filled with hydrogen by upward displacement. In the same way, test chlorine collected by downward displacement. Fill the tubes again with the two gases respectively, add to each a few drops of blue litmus, shake the mixtures strongly and test them again.

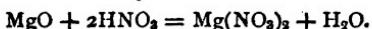
b. Fill two test tubes over strong solution of salt with mixtures of hydrogen and chlorine, containing respectively 1 volume of hydrogen to 3 of chlorine, and 1 of chlorine to 3 of hydrogen, roughly estimated by measurement in the tubes themselves; allow the tubes to stand over the salt water in direct sunlight for five minutes, then remove them separately, and repeat the match and litmus tests. Hydrogen and chlorine combine only in the proportion of 1 to 1 by volume.

2. Put into the bottle gasometer mixtures of hydrogen and oxygen in the proportions of H : O, 2H : O, H : 2O, successively. Blow a few bubbles of each mixture into a dish of soap suds, and, *carefully removing the gasometer to a distance*, light the bubbles with a match held in the pincettes. Force the last portions of each mixture out of the gasometer before introducing one of new proportions.

3. Add sodium chloride solution, drop by drop, to a mixture of 1 c.c. of silver nitrate and 5 c.c. of water, till no further change is produced, then add silver nitrate in the same way, and so on, several times alternately.

4. Add 1 c.c. of sodium hydrate to 6 c.c. of water, drop in a piece of blue litmus paper and add HCl, drop by drop, till a permanent change of color occurs; then add sodium hydrate.

5. Pour HNO₃ over 0.5 gm. of magnesia, shaking the tube at intervals; when all of the solid has disappeared, add more of it till a portion remains undissolved; then add more HNO₃, and so on, several times alternately.



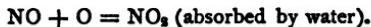
6. Add ammonium hydrate to 1 c.c. of cupric sulphate; when the liquid has become deeply colored throughout, add HCl until a change occurs; then repeat the treatment with ammonium hydrate.

7. Repeat experiment 5, using zinc oxide instead of magnesia, and H₂SO₄ instead of HNO₃.

B. Multiple proportions.—In the case of certain elements there may be more than one of the definite proportions mentioned above.

1. Put together 1 gm. of copper foil and 10 c.c. of HNO₃, attach the adapter and exit tube, and, after allowing the gas, nitric oxide, to escape for two minutes, conduct it into a test tube half full of oxygen inverted over water. Observe especially the result of mixing the gases.

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2. Pass a current of dry oxygen and one of dry sulphurous oxide, made in the usual manner in a test tube, through an ignition tube containing a tuft of platinized asbestos, using the Y tube in order to introduce the gases simultaneously. Connect the free end of the ignition tube with a narrow tube dipping into 3 c.c. of barium chloride. After passing the gases for a few minutes, heat the tuft of asbestos and continue the current of the mixed gases.



C. Instability of combinations in higher proportions.—When an element unites in more than one proportion with another, a part is, in general, less strongly held in combination, especially in the compound containing it in the highest proportion. From the following list of existing compounds experimental illustrations of this principle will be selected.

OXIDES.

Manganous oxide, MnO .

Manganic oxide, Mn_2O_3 .

Manganese dioxide, MnO_2 .

Manganic anhydride, MnO_3 .

Permanganic anhydride, Mn_2O_7 .

Ferrous oxide, FeO .

Ferric oxide, Fe_2O_3 .

Chromic oxide, Cr_2O_3 .

Chromic anhydride, CrO_3 .

CHLORIDES.

Stannous chloride, SnCl_2 .

Stannic chloride, SnCl_4 .

Ferrous chloride, FeCl_2 .

Ferric chloride, Fe_2Cl_6 .

Mercurous chloride, Hg_2Cl_2 .

Mercuric chloride, HgCl_2 .

The compounds MnO_2 , Mn_2O_3 , Mn_2O_7 , Fe_2O_3 and CrO_3 all

yield oxygen readily, and are used as oxidizing agents, while those containing less oxygen yield it only under the strongest reducing influences. In the same way SnCl_4 , Fe_2Cl_6 and HgCl_4 yield chlorine more readily than the compounds FeCl_3 , SnCl_2 and Hg_2Cl_4 .

1. Put together 2 c.c. of ferrous sulphate carefully freed from ferric salts, and 1 c.c. of manganese sulphate, compounds containing the oxides FeO and MnO , add a few drops of H_2SO_4 , and finally, a drop of potassium sulphocyanate, which gives a deep red color with *ferric* solutions, while it is unaffected by *ferrous* compounds; it is therefore used in this experiment to determine the state of oxidation in which the iron exists.

2. Repeat experiment 1, using, instead of manganese sulphate, one drop of a solution of potassium permanganate, which contains the highest oxide, Mn_2O_7 , and compare the result with that obtained with manganese sulphate.

3. Repeat experiment 1, using a solution of chrome alum, a compound containing Cr_2O_3 , instead of manganese sulphate.

4. Repeat experiment 1, using a few drops of potassium dichromate, a compound containing CrO_3 , instead of manganese sulphate.

5. To 2 c.c. of the yellow solution of ferric chloride add 1 c.c. of stannous chloride; then test the solution with a drop of potassium sulphocyanate.

6. Repeat experiment 5, using SnCl_4 instead of SnCl_2 .

7. To 1 c.c. of mercuric chloride add 3 c.c. of stannous chloride.

8. Repeat experiment 7, using SnCl_4 instead of the stannous salt.

CHAPTER XI.

Chemical change in atmospheric air.—Effect of exclusion of the air.—Atmospheric air is itself changed.—Preparation of oxygen.—Chemical activity of oxygen at different temperatures.—Direct oxidation by means of compounds rich in oxygen.—Combustion.—Flame.—More volatile substances more readily inflamed.

A. Chemical change in the atmosphere.—Chemical change may result from simple exposure to the air, with or without the aid of heat.

1. Mix 2 c.c. of ferrous sulphate with an equal volume of ammonium hydrate, pour the product on a piece of filter paper, and expose it to the air for fifteen minutes.



2. Put 2 c. c. of ammonium hydrate into an evaporator, place a strip of copper foil partly within the liquid and partly exposed to the air, leave it for fifteen minutes, and observe any change in the metal or in the liquid.

3. Put a granule of phosphorus in a mortar with a few drops of water and a bit of blue litmus paper, flatten the granule with the pestle till it adheres as a thin sheet to the mortar, and leave it in such a position that it will be partly immersed in the water; after fifteen minutes, look for evidences of chemical action.



4. Heat copper foil in the flame, at first gently, frequently removing it to note any change that may take place, and finally, heat to full redness.

5. Heat a piece of zinc foil in the point of the flame; also heat 1 gm. of zinc on the lid of a porcelain crucible for five minutes.

6. Heat 1 gm. of lead foil on a crucible lid five minutes.

7. Heat 1 gm. of tin in the same way.

B. Effect of exclusion of the atmosphere.—These changes will not take place if the air is excluded, nor when the same substances are exposed to other gases under similar conditions.

1. Heat 1 gm. of tin in a crucible with 2 gms. of a mixture of equal parts of sodium carbonate and potassium carbonate, and, after the fusion has been maintained three minutes, and the crucible has been allowed to cool, separate the products by hot water and examine the insoluble residue.

2. Heat a piece of copper foil in an ignition tube through which a current of hydrogen is passing, for a minute or two, remove the lamp and continue the current of gas till the tube has become cool, and then examine its contents.

3. Repeat the experiment, using carbon dioxide, instead of hydrogen.

4. Repeat experiment 3 with tin foil, instead of copper.

C. Atmospheric air is itself changed.—The atmosphere gives up something, or is altered in composition in effecting these changes.

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1. Flatten a granule of phosphorus between pieces of writing paper by pressure with a pestle, attach the thin sheet of phosphorus thus obtained to a piece of wire and insert it into a test tube of air inverted over water; mark the height of the water within the tube, and, after twenty-four hours or more, note any change in the volume of air; then close the mouth of the tube with the thumb under water, remove the tube and test the remaining gas with a glowing match.

2. Put a granule of phosphorus on a small flat cork, float the cork on water in a dish, ignite the phosphorus with a hot wire and carefully invert over it a small jar through the mouth of which the cork passes readily; when combustion has ceased, slip a glass plate under the mouth of the jar, still kept under the surface of the water, remove the jar, and quickly test the remaining gas with a lighted match.

Fill the same jar with air and repeat the test with the match.

3. Perform a similar experiment with a short piece of wax taper standing upright on a piece of cork floating in a dish of water, and covered while burning with a wide-mouthed pint bottle.

4. Put 5 c.c. of ammoniacal cuprous chloride into a large test tube, close the mouth of the tube tightly with the thumb and shake its contents strongly; then invert it in the pneumatic trough, remove the thumb and allow the water to enter freely, close again with the thumb, reverse the tube, and quickly test the gas that remains with a lighted match.

D. Preparation of oxygen.—Oxygen is usually prepared by strongly heating some compound containing a large proportion of it. This compound may be simply one of oxygen with another element, or it may be more complex, consisting of two elements in union with oxygen.

1. Heat 5 gms. of manganese dioxide in a matress of hard glass 15 cm. long, collect the product, by means of the adapter and

exit tube, in large test tubes inverted over water and reserve it for future experiments.

2. Mix 10 gms. of potassium chlorate in coarse powder with 3 gms. of powdered manganese dioxide, or ferric oxide, heat the mixture in a large, dry test tube, and collect the product as before, using small jars instead of test tubes; let the jars stand mouth downwards in water till required for future experiments.

E. Chemical activity of oxygen at different temperatures.—The chemical activity of oxygen at common temperatures is very slight as compared with its activity at more or less elevated temperatures.

This greater activity of oxygen at higher temperatures furnishes another series of illustrations of a principle stated in chapter VII.

1. Put a piece of sulphur into a deflagrating spoon and plunge it into a jar of oxygen; then heat the sulphur till it inflames and quickly immerse it again in the gas.

2. Repeat experiment 1, using a granule of phosphorus, instead of sulphur.

3. Immerse a bit of charcoal, fastened to a wire, in a large test tube of oxygen; then heat it to redness in the lamp flame and immerse again.

4. Heat a piece of watch spring in the lamp flame till it becomes flexible, wind it around a lead pencil, dip the tip of the spiral thus formed into melted sulphur in a small porcelain crucible; then attach the spiral to a wire and plunge it into a jar of oxygen. Ignite the sulphur, and quickly repeat the immersion in oxygen.

The bottom of the jar, in this experiment, should be covered with a layer of moistened sand 1 cm. thick, and should be filled with oxygen, from a reservoir, by downward displacement.

5. Pass a current of oxygen, from a reservoir, over a slip of

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zinc foil in an ignition tube, and gradually heat the tube up to full redness.

6. Put 2 volumes of hydrogen in the bottle gasometer, and then add 1 volume of oxygen; force a few bubbles of the mixed gases into a small dish of soap suds, by means of the exit tube, and, *after carefully removing the dish to a distance from the gasometer*, apply a lighted match, held in the pincettes, to the mass of bubbles.

F. Direct oxidation by means of compounds rich in oxygen.—Examples of oxidation have just been given in which free oxygen gas was used to effect the oxidation by direct union with the substance oxidized. Many compounds rich in oxygen, or in which the element is loosely held in combination, may be used for the same purpose.

1. Fuse 5 gms. of potassium nitrate in a crucible, and throw in small fragments of sulphur.
2. Repeat the experiment, using charcoal, in place of sulphur.
3. Fuse 0.5 gm. of zinc in a crucible, and drop in small crystals of potassium nitrate.

G. Combustion.—The term combustion, as ordinarily used, refers to a form of chemical action attended with the evolution of sufficient heat to raise a portion or all of the substances engaged in the reaction, to incandescence, that is, to the temperature at which light is given off. Combustion is usually a process of oxidation, or the combination of the burning body with oxygen.

All ordinary combustible bodies owe their combustibility to the carbon and hydrogen that they contain; these unite with the oxygen forming carbon dioxide and water, if the supply of oxygen is sufficient. If the combustible body contains a large proportion of oxygen it will burn without giving much light; if a smaller proportion of oxygen is combined in it, the light will be brighter, while if there is little or no oxygen the flame will be smoky.

1. Put 1 gm. of sugar, a substance containing fifty-one per cent. of oxygen, on the inverted lid of a porcelain crucible and heat it, slowly raising the temperature.
2. Perform a similar experiment with 1 gm. of stearine, cut from a common stearine candle; stearine contains about ten per cent. of oxygen.
3. Perform a similar experiment with rosin, a substance containing about eight per cent. of oxygen.
4. Saturate a folded slip of filter paper with alcohol, a substance containing thirty-seven per cent. of oxygen, and set fire to it.
5. Perform a similar experiment with oil of turpentine, containing no oxygen.

H. Flame.—Flame is burning vapor or gas. In the case of a combustible from which no vapor can be formed at the temperature of the combustion, there can be no flame. Some experiments that have already been performed illustrate this principle in a striking manner.

1. Burn some fragments of charcoal on the platinum foil.

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I. More volatile substances more readily inflamed.

—As a rule, the more readily a substance is converted into vapor, the more readily it will inflame.

An important application of this principle is made in the usual method of testing the quality of kerosene oils, which, in order to be safely used, should not inflame below a certain temperature.

1. Heat the end of a piece of stout iron wire red-hot and plunge it into 1 c.c. of carbon disulphide in a small crucible; this liquid boils at 43° C.

2. Repeat the experiment, using alcohol, which boils at 78° C., instead of carbon disulphide.

3. Plunge a lighted match into alcohol in a small crucible.

4. Repeat the experiment, using whale, lard or olive oil in the place of alcohol; these oils do not boil even at temperatures so high as to decompose them.

5. Fill a 2 inch evaporator with kerosene oil to within 6 mm. of the top, and float it in a large evaporator containing about a quarter litre of cold water. Confine the smaller vessel with a triangle so that it may remain at the centre of the larger, and suspend a thermometer so that its bulb may be completely immersed in the oil. Heat the water in the larger dish very slowly and when the temperature of the oil has reached 75° F., (24° C.) pass over the surface of the oil exactly on a level with the top of the small evaporator a minute gas flame less than 5 mm. in length, burning at the end of a glass tube. Repeat this test for each two degrees Fahrenheit or one degree Centigrade that the oil increases in temperature, watching the surface of the oil closely. At the instant when a momentary flash of pale, blue flame is produced by the application of the test flame, note the temperature of the oil and extinguish the lamp under the larger dish.

Should the oil take fire and continue to burn, it may be extinguished by a disc of tin plate somewhat larger than the top of the oil vessel, and which should always be kept at hand during the experiment. In performing the above experiment it is ad-

visable, for perfect security, to make use of a shallow tray of tin plate or sheet iron, 40-50 cm. square, within which all apparatus required may be kept during the experiment.

6. Repeat the experiment with a fresh quantity of kerosene, which has been thoroughly mixed with 2 c.c. of naphtha or common benzine.

The above experiments involve the principles of the commercial tests for kerosene. The laws of different States have prescribed the conditions of the test with great minuteness, regulating the shape and capacity of the vessels used, the quantities of oil and water, the time of heating, and especially the minimum temperature, which may be indicated by a thermometer suspended in the oil at the instant when the phenomenon of "flashing" occurs.

The temperature of 110° Fahr. (43° C.) may be considered as the lowest allowable limit for the flashing point of the oil used for burning in lamps. The burning point, *i. e.*, the temperature at which an oil takes fire from the test flame, should be considerably higher than this.

CHAPTER XII.

The nature of bright flames.—Structure of bright flames.—Extinguishing a flame.—Combustion not necessarily oxidation.—Explosive substances.—Colored flame reactions.—Flame reactions of compound substances. Predominance of the color due to one constituent of the compound.—Exceptions.—Predominance of color of one metal over another.—Pyrotechny.

A.—The nature of bright flames.—The luminosity of bright flames is probably due to the presence in them of solid, white-hot particles, resulting from the decomposition of the vapors mentioned above.

1. Hold a small coil of fine platinum wire in the non-luminous flame of a Bunsen burner or an alcohol lamp. The coil may be made by winding a thin wire eight or ten times around a match or a very small glass rod.
2. Sprinkle some finely powdered lime, a non-volatile and incombustible substance, into a non-luminous flame.

B. Structure of bright flames.—The flame of a lamp or candle consists of three distinct parts, as follows:

a. An outer non-luminous mantle, completely enveloping the flame, in which the supply of oxygen is unlimited and the combustion perfect.

b. An inner non-luminous cone made up of combustible gases (hydrocarbons), which, owing to the exclusion of oxygen by the outer part of the flame, are prevented from burning while in that position.

c. A hollow cone intermediate between *a* and *b*, in which the supply of oxygen is imperfect and the combustion therefore incomplete. This portion probably consists, in the main, of fine particles of solid matter heated to incandescence.

1. Cut a piece of cardboard, by successive trials, till it is of such size and shape as to just hide the luminous cone, *c*, from the eye, when held close to the flame; then look for the non-luminous mantle, *a*, outside of this. The flame for this experiment should be large and regular in shape and sheltered from draughts of air.

2. Hold a match horizontally across the flame of a candle, so that its middle portion lies within the flame, just above the wick.

3. Press a piece of writing paper quickly down on the flame of a candle till it almost touches the wick, and remove it in the same way, before it takes fire.

4. Thrust the head of a match quickly into the middle of a candle flame, and remove it, after a moment, in the same manner.

5. Connect a narrow glass tube, 10 cm. long, drawn out to a fine opening and slightly curved at one end, by an adapter filled with moist cotton loosely packed, with the gas bottle of the bottle gasometer, which should be filled with water as usual; insert the

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point of the small tube in a flame just above the wick (in the centre of the cone *c*), and allow the water to pass over into the graduated bottle.

When the gas bottle is half filled with gas, remove the tube from the flame, force the water back into the gas bottle, and apply a flame to the stream of vapor that issues from the pointed tube.

C. Extinguishing a flame.—A flame, burning under ordinary circumstances, may be extinguished in any one of three ways:

- a.* By depriving it of material that will burn, or what is usually termed the combustible.
- b.* By depriving it of oxygen, usually termed the supporter of combustion.
- c.* By cooling the flame.

The first method needs no illustration; the second has already been illustrated by several experiments that may be called to mind; to illustrate the third method—

1. Press down a piece of wire gauze, 8 cm. square, upon the flame of a candle.
2. Put 10 c.c. of alcohol into an evaporator, light it, and pour it, while burning, in a thin stream through a piece of wire gauze into another evaporator.
3. Wind a piece of copper wire about 1 mm. in diameter eight or ten times around a lead pencil. Then encircle the flame of a candle in this coil by moving it downwards over the flame.

D. Combustion not necessarily oxidation.—Chemical action accompanied by light and heat may take place without the aid of oxygen.

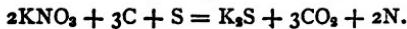
1. Plunge a lighted paraffine taper into a test tube of chlorine.
2. Fuse 5 gms. of sulphur in a large, dry test tube, and when it begins to boil, plunge into the vapor a deflagrating spoon containing a granule of sodium.

E. Explosive substances.—Explosive substances are those that contain combustible matters more or less intimately associated with oxygen in forms of combination in which it is loosely held. The combustible and the compound of oxygen may be simply intimately mixed together, or they may be chemically combined, as in gun-cotton and in nitroglycerine.

In such a substance, the combustion being once started proceeds with great rapidity, and with the sudden evolution of a large volume of gaseous products of combustion heated to a high degree of temperature, and in consequence, greatly expanded.

1. Mix together intimately, with a spatula, on smooth, white paper, 0.5 gm. of charcoal and 4 gms. of thoroughly dried potassium nitrate, each previously ground to a fine powder separately, and 0.5 gm. of sulphur, with care to avoid any concussion or hard pressure, then transfer the mixture to a mortar, add enough water, with constant stirring, to make a thick paste, mix again and, finally, granulate the mixture by pressing it with a pestle through wire gauze, and let it dry in a safe place. The product is ordinary gunpowder.

Apply flame to a small quantity of it and explain the result.



2. Make a mixture of potassium nitrate and charcoal powder

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alone, in the proportion given above, and in the same manner, and apply the same test to it.

3. Examine the comparative combustibility of sulphur and charcoal, by heating a granule of each, 1 cm. apart, on the lid of a porcelain crucible, or a slip of sheet iron, and apply this result in explanation of the results obtained in experiments 1 and 2.

F. Colored flame reactions.—Many elementary substances, when brought into the colorless flame of an alcohol lamp or Bunsen burner, are converted into vapor, and they then communicate characteristic colors to the flame.

1. Hold a piece of copper wire at the point of the inner, blue cone of the Bunsen flame, or of the alcohol lamp flame.
2. Repeat the experiment, using a narrow strip of sheet zinc in place of the copper wire.
3. Perform a similar experiment with a wire of brass, an alloy of copper and zinc.
4. Heat a granule of sodium on the inverted lid of a porcelain crucible.

G. Flame reactions of compound substances.—For the illustration of the preceding principle, we need not confine ourselves to the use of the elementary substances themselves, but we can use their compounds; in the intense heat of the flame the compound is broken up (dissociated) and the color due to the vapor of one or another of the elements appears. The chlorides being easily volatilized are best suited for the illustration of this principle.

1. Dip the moistened loop of the fine platinum wire into powdered sodium chloride, and hold it in the flame.
2. Perform a similar experiment with (a) potassium chloride, (b) lithium chloride, (c) barium chloride.

H. The color due to one constituent of the compound predominating.—At the temperature of the flame the vapors of the metallic elements emit more light than those of the non-metallic elements. Hence, when various compounds of the same metal are brought into the flame, the color due to the metal is presented in nearly all cases.

1. Repeat the flame test in G. 1, with sodium carbonate, and then with sodium nitrate.
2. Repeat again, with the corresponding potassium salts.

I. Exceptions to the preceding rule. In rare cases, however, the behavior of the compound may differ in this respect from that of the metal contained in it.

1. Heat a piece of copper foil or wire in the flame; then dip it into **HCl** in a watch glass, and heat again.
2. Repeat the experiment, using a drop of bromine covered with water in an evaporator, instead of **HCl**.
3. Repeat again, using a drop of tincture of iodine instead of **HCl**.

K. Color produced by one metal predominating over the color of another.—Different metals emit

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light of different degrees of intensity when raised to the same temperature in the flame of the gas burner or in any other way. Hence, if two metallic elements are present simultaneously in a flame, the colored light emitted by one may be so strong as to mask the light emitted by the other.

Colored transparent media may sometimes be used to intercept certain colors in this case.

1. Dip the platinum wire loop in an intimate mixture of finely powdered sodium chloride and potassium chloride, and hold it in the lamp flame as before.

2. Repeat the experiment, and hold a piece of blue glass between the eye and the colored flame.

L. Pyrotechny.—In pyrotechny, or the art of making fire-works, we have the combined application of the principles stated in E, and in F and G.

1. Pulverize separately 4 gms. of well dried strontium nitrate and 1 gm. of potassium chlorate, and mix these powders, together with 1 gm. of sulphur and 0.25 gm. of lampblack, intimately together with a spatula on smooth paper, and, finally, apply a lighted match to a portion of the mixture on a piece of sheet iron.

2. Pulverize 3 gms. of potassium chlorate, and mix the powder with 1 gm. of sulphur and 0.5 gm. of cupric oxide, on paper with a spatula as before, and apply flame to a portion of the mixture.

3. Mix intimately 4.5 gms. of well dried and finely powdered barium nitrate, and 1 gm. of potassium chlorate, with 1.5 gms. of sulphur, and 0.25 gm. of lampblack, as before described, and apply flame.

In order that the pyrotechnical experiments shall succeed, the quantities given must be weighed out, and all the materials must be dry and very finely powdered.

CHAPTER XIII.

Term "reduction" defined.—Carbon as a reducing agent.—Substitution.—Desulphuration.—De-chlorination.

A. The term "reduction" defined.—The term reduction is applied to a chemical process which is directly the reverse of oxidation, *i. e.*, it implies the abstraction of oxygen from substances containing it. This may be accomplished simply by the action of heat on an oxidized body, or by means of some substance which has, under the existing conditions, a greater attraction for oxygen; the aid of heat may or may not be requisite in the latter case.

1. Heat 1 gm. of mercuric oxide in a matrass.
2. Heat 1 gm. of potassium chlorate strongly in a small, dry test tube, and thrust a glowing taper into the mouth of the tube.
3. Invert a large test tube, full of water, in the pneumatic trough; then enclose a granule of sodium in a little cage made by folding a small piece of wire gauze, and hold it, with the pincettes, under the mouth of the test tube till all action has ceased; finally, test the product in the tube with a lighted match.

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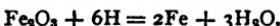
4. Heat a granule of sodium or potassium, previously freed from benzine by pressure between folds of filter paper, in an ignition tube through which a stream of well dried carbon dioxide is passing, remove the lamp after a moment, and continue the current of gas till the tube is cool; then wash the contents of the tube into a small evaporator and examine the residue.



5. Heat 1 gm. of cupric oxide to redness in an ignition tube through which a slow stream of hydrogen is passing, and hold the dry outer surface of a test tube containing cold water, close to the mouth of the tube; then remove the lamp, and, when the tube is cool, shut off the current of gas and examine the contents of the tube.



6. Pass a current of well dried hydrogen through an ignition tube containing finely powdered ferric oxide, and, when the whole apparatus is filled with the gas, heat the tube and its contents to redness, holding the outside of a test tube, containing cold water, close to the mouth of the tube; finally, sprinkle the contents of the tube while still warm, out into the air.



7. Heat an intimate mixture of 2 gms. of fine saw dust and 0.5 gm. of lead oxide strongly in a porcelain crucible, transfer the resulting mass to the mortar, and grind it up with water, pouring off the lighter portions; finally, look for metallic products of reduction in the heavier portions of the powder.

B. Carbon as a reducing agent.—Carbon at elevated temperatures is a powerful, and one of the most useful, reducing agents. With its aid most of the metals used in the arts are reduced to the metallic condition.

1. Dip a charcoal splinter into powdered cupric sulphate, and heat it to redness in the lamp flame; let the burnt end drop into

a mortar containing a little water, and grind it to powder with the pestle, using considerable pressure, and carefully examine the heavier portions of the powder.

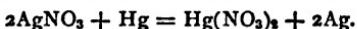
2. Perform a similar experiment with lead acetate.

3. Perform a similar experiment with ferrous sulphate, except that the burnt end of the splinter should be powdered without the addition of water; search for products of reduction in the powder with the aid of a small magnet.

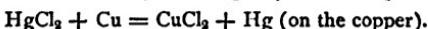
4. In the pointed, closed end of a small matrass, put a granule of arsenious oxide, and over it put two or three small splinters of charcoal; then heat this end of the tube in the lamp flame, with care to bring the charcoal to a red heat at first.

C. Substitution.—A metal may in many cases be separated from its combination with other elements, and be obtained in the free state, by the direct substitution of another metal for it in the compound. This reaction is similar in its results to a process of reduction.

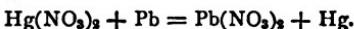
1. Add a drop of mercury to 2 c.c. of silver nitrate and allow the mixture to stand without disturbance for an hour.



2. *a.* Put a slip of copper foil into a tube containing 2 c.c. of mercuric chloride; after a moment, remove the foil, rub it strongly with a piece of dry cloth or chamois skin, note its condition, and finally, heat it gently in the lamp flame.



b. Suspend a strip of thin lead foil in a small test tube filled with mercuric nitrate solution, let it stand five minutes and closely observe its behavior in the solution.



3. *a.* Suspend a strip of well cleaned sheet zinc in a test tube half filled with lead acetate solution, and set the tube aside for an hour.

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5. Repeat experiment 4, using cupric sulphate instead of lead acetate, and after five minutes remove the zinc and examine it in a good light.
4. Suspend a strip of magnesium ribbon in a solution of zinc sulphate.



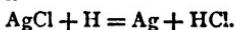
Finally, compare together the results of experiments 1, 2, 3 and 4, observing especially the order in which they are given.

D. Desulphuration and dechlorination.—It has been seen that metals burn in chlorine, and in vapor of sulphur, with an energy comparable with that exhibited during their combination with oxygen. The analogy is further exhibited in processes of desulphuration and dechlorination similar to that of deoxidation or reduction.

1. Conduct a stream of well dried hydrogen through an ignition tube containing 1 gm. of dry, pulverized silver sulphide, and heat the tube; observe the odor of the gas issuing from the free end of the tube, and its action on lead paper; then light the gas and hold a dry test tube containing cold water in the flame; finally, examine the residue in the tube, by pressing it strongly under the pestle, or heating it in the flame.



2. Repeat experiment 1, using 0.2 gm. of dry silver chloride instead of the sulphide, and test the gas issuing from the free end of the tube with litmus papers; finally, examine the residue in the tube as before.



CHAPTER XIV.

Classified list of elements.—Explanations of the table.—Similarity between members of the same group.—Members of same group not in all respects alike.—Resemblance between compounds of members of same group.—Marked differences between members of different groups.—Compound radicals.—Ammonium.—Cyanogen.—Another classification of the elements, for a special purpose.

A. *Table of the principal elements.*—The resemblance between certain elements with respect to their more important chemical properties may be made the basis of their arrangement in groups.

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Group.	Name.	Symbol.	Atomic Weight.	Prevailing Quantivalence.	Dominant Electrical Character.	State of Aggregation.
I.	Hydrogen, ...	H	I	I	+	Gas.
II.	Bromine, ... Chlorine, ... Fluorine, ... Iodine, <i>Cyanogen</i> , ...	Br. Cl. F. I. <i>CN.</i>	80 35.5 19 127 26	I I I I I	— — — — —	Liq. Gas. Solid. Gas.
III.	Lithium, Potassium, ... Sodium, ... <i>Ammonium</i> ,	Li. K. Na. <i>NH</i> ₄	7 39.1 23 18	I I I I	++ ++ ++ +	Solid. " " "
IV.	Silver,	Ag.	108	I	+	Solid.
V.	Oxygen, Sulphur,	O. S.	16 32	II II.IV.VI	— —	Gas. Solid.
VI.	Barium, Calcium, Lead, Strontium, ...	Ba. Ca. Pb. Sr.	137 40 207 88	II II II II	++ ++ ++ ++	Solid. " " "
VII.	Cadmium, ... Magnesium, ... Zinc, Copper,	Cd. Mg. Zn. Cu.	112 24 65 63.4	II II II II	++ ++ ++ ++	Solid. " " "
VIII.	Mercury, ...	Hg.	200	II	+	Liq.

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Group.	Name.	Symbol.	Atomic Weight.	Prevailing Quantivalence.	Dominant Electrical Character.	State of Aggregation.
IX.	Aluminum, - Chromium, - Cobalt, ----- Iron, ----- Manganese, - Nickel, -----	Al. Cr. Co. Fe. Mn. Ni.	27.3 52.4 58.6 56 55 58.6	IV IV.VI II II.IV II.IV II	++ + + +++ +	Solid. " " " " "
X.	Gold,.....	Au.	196.6	III	+	Solid.
XI.	Boron,	B.	11	III	-	Solid.
XII.	Antimony, .. Arsenic, Bismuth, Nitrogen, ... Phosphorus,	Sb. As. Bi. N. P.	122 75 207.5 14 31	III.V III.V III.V III.V III.V	+ . - - Gas. Solid.	Solid. " " Gas. Solid.
XIII.	Platinum, ...	Pt.	196.7	II.IV	+	Solid.
XIV.	Tin,.....	Sn.	118	II.IV	+	Solid.
XV.	Carbon, Silicon,	C. Si.	12 28	IV IV	- -	Solid. "

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Symbols.—The symbols of the elements are abbreviations, generally of their Latin names. A collection of symbols representing a compound is called a formula, and an arrangement of symbols and formulas in an equation is used to illustrate the reaction of substances on one another.

Atomic weights.—The atomic weights in the second column represent the smallest weight of each element entering into combination, compared with an atom of hydrogen taken as unity. These weights, taken absolutely, are so small that it is beyond our power at present to determine what fraction of a gramme one atom of an element weighs; but it is possible to determine with great accuracy the relative weights of the atoms. Thus, if 1 be taken as the smallest weight of hydrogen entering into combination, the smallest weight of oxygen entering into a combination will be 16; that of sulphur 32, and so on, as given in the column of atomic weights.

The symbol of an element in a formula or equation has a double signification, representing, not only the element itself, but a relative quantity of that element indicated by its atomic weight. The number of atoms of the element taken is indicated by figures associated with the symbol. A small figure on the line at the right of the symbol affects

only the symbol to which it is attached. By the formula NH_4Cl , for instance, we indicate not only that nitrogen is taken once, hydrogen four times, and chlorine once, but also that there are in combination 14 parts by weight of N, 4 of H (4×1), and 35.5 of Cl. A large figure affects all the elements whose symbols follow it, up to a mark of punctuation or an algebraic sign. When parentheses are used, figures, however placed, outside of the parentheses, affect all symbols within, while figures included in the parentheses follow the rules above stated. In this formula of common alum, $2(\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 + 24\text{H}_2\text{O})$, we have, according to these rules, 4 atoms of potassium, 4 of aluminium, 96 of hydrogen, 8 of sulphur and 80 of oxygen.

Quantivalence.—It will be observed, in the formulas and equations already used, that one atom of H is united in some cases with one of another element, as in HCl , while in other cases two or more of H may be united with a single atom, as in H_2O , H_2S , NH_3 , etc. The atom-fixing power of an element, measured by the greatest number of hydrogen atoms or their equivalents which it can hold in combination, is called its *atomicity*, and is indicated, when desired, by a Roman numeral, or by short dashes in connection with the symbol. Thus, the atomicity of Cl, Br or Na is I; of O or Ca, II; of N

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or P, III or V. Elements whose atomicity is one are called *monad* elements, while those whose atomicity is two, three, four, five, or six are called *dyad*, *triad*, *tetrad*, *pentad* and *hexad* elements, respectively.

Any element may be regarded as existing in an unsatisfied condition when combined with a lesser number of hydrogen or other atoms than it is capable of fixing in combination. The oxygen in the formula H—O—* is unsatisfied because it is a dyad element, while in H—O—H, all of its attractions are satisfied and the molecule H_2O is said to be *saturated*. In like manner it may be shown that in Na—O—, —Ca—Cl, or —O—N≡O₂, certain elements are unsatisfied, while the formulas Na—O—Na, or Na₂O, Cl—Ca—Cl, or CaCl₂, Na—O—N≡O₂, or NaNO₃, represent saturated molecules.

A saturated molecule may sometimes consist of two or more atoms of the same element, as in H—H, O—O—O (ozone, an allotropic form of oxygen).

Certain elements possess several degrees of atom-fixing power; while the highest degree of this power is distinguished by the name atomicity, the term *quantivalence* is used to designate the degree of this

* The bars or "bonds" in these examples are arbitrarily used to represent the supposed disposition of the forces acting between the atoms.

power in special cases, or in certain classes of compounds. Thus, iron behaves as a dyad element in the ferrous compounds, and as a tetrad in the ferric compounds.



Nitrogen exhibits both triad and pentad characters. Sulphur is dyad in the sulphides, tetrad in the sulphites, and hexad in the sulphates. This variation in quantivalence, when it occurs, consists always in a gain or loss of an even number of bonds; elements, therefore, whose atomicity is represented by an odd number (*perissads*), are odd in all degrees of quantivalence, while elements of even atomicity (*artiadis*) are always even. In the table the prevailing quantivalence, *i. e.*, the degree of quantivalence most frequently occurring in compounds of the element, is given.

On comparing the two members of any of the equations already given, it will be seen that the number of atoms of any element represented is the same in each member; also, that no unsatisfied atom is shown in the right-hand member, except, perhaps, in the case of a free element; in this case the principle may be made to hold good by simply doubling all terms of the equation. In this connection it must be remembered, in writing equations, that two

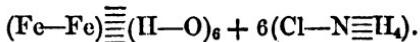
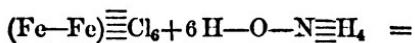
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atoms of a monad element are required to combine with or replace one of a dyad, two of a dyad for one of a tetrad, and so on; the quantivalence of each element may be found in the table.

In writing reactions in which H_2SO_4 , HNO_3 , $HC_2H_3O_2$ (acetic acid) and H_2O are concerned, it will be seen in most cases that the groups SO_4 , NO_3 , $C_2H_3O_2$ and HO are moved from one side of the equation to the other unchanged, and that the group SO_4 has a combining power equivalent to two of hydrogen, as shown by the hydrogen atoms united with it; that the combining power of each of the other groups is equivalent to one of hydrogen is indicated in the same manner.

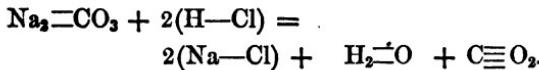
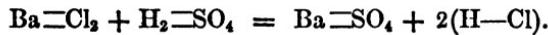
The combining power of such a group must, in all cases, be satisfied on the right hand side of the equation.

The following equation is given to illustrate the preceding statement.



Iron being a tetrad, the total number of bonds for the two atoms is eight, of which two are taken up between the atoms of Fe, forming a group of which the atomicity is six. Four of the bonds belonging to N in the first member are taken up by four

atoms of H, and the remaining bond by O; this element, in its turn, has one bond left free for the attachment of another atom of H, by which the molecule NH₄HO is completed. On the other side of the equation the one odd bond of N is united with Cl, a monad element, forming the saturated molecule NH₄Cl, while the group H—O—, taken six times, unites with the iron group in the place of 6Cl. Further illustration of the same principle will be found in the following equations.



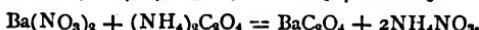
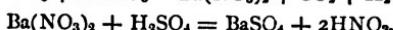
Electrical character.—In the decomposition of a binary compound, such as NaCl, by the galvanic current, one of the elements appears at the positive pole, or that connected with the carbon or platinum, and is called the negative element, while the other, called the positive element, appears at the negative or zinc pole. Certain elements of strongly marked chemical character always appear at the positive pole, others of opposite, though as strongly marked character, always appear at the negative pole, while others still, occupying an intermediate position, exhibit an electrical character the opposite of that of

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strongly marked elements with which they combine. Even elements of the latter class, however, in nearly all cases possess a dominant electrical character, either positive or negative. This dominant character is indicated in the table by a + or - sign, as the case may be. Elements of unlike electrical character tend to unite more readily than those of like character, and to form more stable compounds.

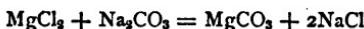
1. Compare bromine, chlorine and iodine as follows:
 - a. Observe the odor of each, very cautiously.
 - b. Close the mouth of a tube containing chlorine with the hand for a moment, do the same with bromine, and, finally, put a granule of iodine on the hand, and observe the action of each substance on the skin.
 - c. Heat a tube containing chlorine; then heat very small quantities of iodine and bromine, separately, in test tubes.
 - d. Put small quantities of bromine and iodine into test tubes loosely closed by corks in the lower end of which are inserted slips of copper foil; then heat the tubes moderately in the lamp flame so that the metal may be freely exposed to the vapors of the two elements: close a tube, filled with chlorine, in the same way with a cork to which a slip of copper foil is attached; finally, after exposure for several minutes, remove the corks and examine the foil in the several cases.
2. Repeat experiment 1 d, using silver foil instead of copper.
3. Repeat again, using zinc foil.
4. Compare potassium and sodium, observing the behavior of each under the following conditions:
 - a. Expose a freshly cut surface to the air.
 - b. Put a small bit of each metal, previously dried by pressure between folds of porous paper, on filter paper floated on water in small dishes.
 - c. Put a piece of red and one of blue litmus paper in the water in each of the dishes used in b.

5. To 1 gm. each of barium carbonate, BaCO_3 , calcium carbonate, CaCO_3 , lead carbonate, PbCO_3 , and strontium carbonate, SrCO_3 , in separate test tubes, add 5 c. c. of water and heat; then add 2 c. c. of HNO_3 and heat again; finally, divide each product into two parts, and to one portion in each case add 1 c. c. of H_2SO_4 , and to the other ammonia till neutral, and then 1 c. c. of ammonium oxalate.



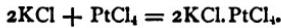
6. Compare zinc and magnesium, as follows, using each in the form of foil or ribbon.

- a. When heated in the air.
- b. When boiled with water.
- c. When treated with HCl.
- d. When 1 c.c. of H_2SO_4 is added separately to 5 c.c. each of magnesium chloride and of zinc chloride.
- e. When 1 c.c. of sodium carbonate is added separately to 5 c.c. of each of the two chlorides.



B. Members of the same group not in all respects alike.—Notwithstanding the marked similarity between members of the same group, there are in all cases notable points of difference, which enable us to distinguish one from another; of these application is made in that branch of chemistry known as qualitative analysis. Only a few of the more striking illustrations of this principle need be cited.

1. To .5 c.c. of concentrated solution of sodium chloride, in a watch glass, add three drops of platinum chloride, and then 1 c.c. of alcohol, and stir the mixture. Repeat the experiment, using potassium chloride instead of sodium chloride.



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2. To 1 c.c. of barium chloride add 10 c.c. of water and a drop of H_2SO_4 . Repeat the experiment, using calcium chloride instead of barium chloride.

3. To 1 c.c. of calcium chloride add a drop of ammonium sulphide. Repeat the experiment, using a solution of lead chloride in hot water instead of calcium chloride.

4. To 1 c.c. each of magnesium chloride, zinc chloride and cadmium chloride add 0.5 c.c. of ammonium sulphide.



5. Boil a granule of starch in 5 c.c. of water and divide the solution into three parts; to one add a drop of bromine water, to another chlorine water, and to a third tincture of iodine.

C. Resemblance between compounds of members of the same group.—On comparing together the compounds of elements belonging to the same groups we find even more marked resemblance than between the elements themselves. This resemblance is particularly striking in the case of the crystalline forms of the substances, and is carried to such an extent that elements of the same group may replace each other in a compound without any change in the crystalline form; such compounds are said to be *isomorphous*.

1. Compare together, by tests with separate portions of 0.5 gm., sodium chloride, potassium chloride and ammonium chloride, observing (*a*) their taste, (*b*) their behavior in the air, (*c*) their solubility in water, (*d*) the appearance of the crystalline residue obtained when the solutions are left to evaporate *slowly* in a watch glass, (*e*) their solubility in alcohol, (*f*) their behavior when heated gradually up to redness in a porcelain crucible, and

(g) when gently heated with H_2SO_4 in a test tube; in the last case test the gaseous products as to their odor and action on litmus paper.

2. Compare in the same manner potassium iodide, bromide and chloride.

3. Compare in the same manner magnesium chloride and zinc chloride.

4. Evaporate slowly, in separate watch glasses, 3 c.c. each of common alum, $K_2SO_4 \cdot Al_2(SO_4)_3 + 24H_2O$, chrome alum, $K_2SO_4 \cdot Cr_2(SO_4)_3 + 24H_2O$, and ammonium iron alum, $(NH_4)_2SO_4 \cdot Fe_2(SO_4)_3 + 24H_2O$, and compare the crystalline forms obtained.

D. Marked differences between members of different groups.—Conversely, we find that compounds of elements that do not belong to the same group differ widely from one another.

1. Compare together, by tests with separate portions, potassium sulphate, ferrous sulphate, cupric sulphate and lead sulphate, observing (a) their solubility in water, (b) their taste, (c) their behavior when heated on the lid of a porcelain crucible, and (d) the action of ammonium hydrate and HNO_3 respectively, on their solutions in water, in case they are soluble.

E. Compound radicals.—Some compound substances resemble certain elements to such a degree that they can be assigned to certain groups of the elements. Ammonium, NH_4 , is the radical supposed to exist in the ammonium salts, although it has never been isolated.

1. Compare ammonium chloride, NH_4Cl , and potassium chloride, KCl , and ammonium bromide and potassium bromide, as to their crystalline form, by evaporating 5 c.c. of a strong solution

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of each salt very slowly in separate watch glasses, pouring off the mother liquor after a few crystals have been formed and examining these crystals with the lens.

2. To 0.5 c.c. of potassium chloride, in a watch glass, add 5 drops of platinum chloride and 1 c.c. of alcohol, and allow the glass to stand undisturbed for half an hour.

3. Perform a similar experiment with ammonium chloride and examine the product in both cases with a lens.

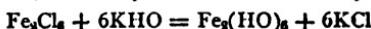


4. Compare the crystalline forms of ammonium nitrate, potassium nitrate, and sodium nitrate, obtained by slow evaporation of the solutions of these salts in separate watch glasses.

5. Compare the crystalline forms of ammonium sulphate, potassium sulphate, and sodium sulphate.

6. Mix together, with vigorous agitation, a solution of 1 gm. of tartaric acid in 4 c.c. of water and of 2 gms. of potassium nitrate in 5 c.c. of water; repeat the experiment using ammonium nitrate instead of potassium nitrate, and compare the two results.

7. To separate portions of a solution of ferric chloride add potassium hydrate, sodium hydrate and ammonium hydrate.



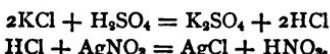
F. Cyanogen as a member of the bromine group.—Cyanogen, CN, closely resembles the members of another group of elements; as it has been isolated, however, it is not, like ammonium, a hypothetical radical.

1. Compare in the usual way the crystalline forms of potassium cyanide and of potassium chloride.

2. To 1 c.c. of silver nitrate add sodium chloride as long as any change appears; then add HNO_3 , and observe the result again; finally, add ammonium hydrate till the liquid, after being shaken, smells strongly of the reagent.

Repeat, using potassium cyanide instead of the chloride, *with care not to inhale the fumes evolved.*

3. To 0.5 gm. of potassium chloride add 5 drops of H_2SO_4 , and, with the looped tube, hold a drop of silver nitrate about 2 cm. above the liquid in the tube.



Repeat the experiment, using potassium cyanide instead of the chloride, with special care not to inhale the fumes evolved.

G. Another classification of the elements, for a special purpose.—The elements and their compounds may be grouped in different ways on different principles of classification. In the system of grouping already given, those substances are brought into the same group whose properties agree in several important respects.

Another method of grouping a part of these substances, based on their behavior with a certain series of reagents, is generally adopted in works on qualitative chemical analysis ; such a classification is very useful for this special purpose, although in some cases elements are brought together which are, in most respects, very different from one another.

These group reagents are hydrogen sulphide, H_2S , ammonium sulphide, $(NH_4)_2S$, and ammonium carbonate, $(NH_4)_2CO_3$.

Group I. Ammonium, potassium and sodium. Not precipitated from their solutions by any of these reagents.

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Group II. Barium, strontium, calcium and magnesium. Precipitated from their *neutral* solutions only by ammonium carbonate, except when combined with phosphoric and certain other acids.

Group III. Aluminium, chromium. Precipitated from their *neutral* solutions as hydrates by ammonium sulphide.

Group IV. Cobalt, nickel, iron, manganese and zinc. Precipitated from their *neutral* solutions as sulphides, by ammonium sulphide.

Group V. Silver, mercury, lead, copper, cadmium, and bismuth. Precipitated from moderately acid or alkaline solutions as sulphides, by hydrogen sulphide ; the sulphides are insoluble in ammonium sulphide.

Group VI. Tin, arsenic, antimony, gold and platinum. Likewise precipitated as sulphides from their acid solutions, but not from alkaline solutions, by hydrogen sulphide ; the sulphides are soluble in ammonium sulphide solution, and are reprecipitated from this solution as sulphides by HCl.

The groups are numbered as in Fresenius's Qualitative Analysis and most other standard works on the same subject.

The student may perform several experiments with solutions of the substances named, in illustration of this principle of classification, taking for each

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experiment not more than 1 c.c. of the solution ; and, in case the solubility of a precipitate obtained by a group reagent is to be examined, separating the precipitate by filtration from the liquid in which it was precipitated.

CHAPTER XV.

Most important binary compounds.—Conversion of certain binary compounds into each other.—Oxides into sulphides.—Oxides into chlorides.—Sulphides into oxides.—Chlorides into sulphides.—Sulphides into chlorides.—Properties of the oxides.—Hydrates.—Basic substances combining with one another.—Most important ternary compounds.

A. Most important binary compounds.—Considered either with respect to the abundance of their occurrence in nature or of their usefulness in the arts, the oxides, sulphides and chlorides of the metals are the most important binary compounds of the elements, *i. e.*, compounds containing but two elements.

1. Compare together the oxides, potassium oxide, K_2O ,^{*} calcium oxide, CaO , and lead oxide, PbO , using 0.5 gm. for each experiment.

* Potassium hydrate, KHO , will exhibit all the essential properties of K_2O , and is to be used here in its place, as the oxide is not easily obtained.

- a. Test the solubility of each with 5 c.c. of water, first cold, then hot.
- b. Heat each in a porcelain crucible two minutes.
- c. Treat each with cold H_2SO_4 ; then warm the liquids.
- d. Treat each as in c., using HNO_3 instead of H_2SO_4 .
2. Repeat the series of experiments with potassium sulphide, K_2S , calcium sulphide, CaS , and lead sulphide, PbS .
3. Repeat again with the corresponding chlorides, KCl , $CaCl_2$ and $PbCl_2$.

B. Conversion of certain binary compounds into each other.—Oxides, chlorides and sulphides may in some cases be converted into each other by the direct action of the element to be substituted in the compound, as, for example, when sulphur is made to act on an oxide, or chlorine on a sulphide. More commonly, however, the sulphur, chlorine or oxygen is used in the form of one of its compounds with hydrogen.

Oxides into sulphides.—1. Mix 0.5 gm. of lead oxide and 1 gm. of sulphur intimately, heat the mixture in the matrass to redness, break the matrass when cold, and examine its contents for evidences of chemical change.

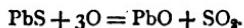
2. Into an ignition tube 20 cm. long and having three interior cavities, put, each in a separate cavity, 0.5 gm. lead oxide, 0.5 gm. of zinc oxide, and 0.5 gm. of arsenious oxide; conduct through the tube a stream of hydrogen sulphide, and light the jet of gas that issues from the free end of the tube; finally, apply heat to the three substances in succession, beginning with the lead oxide nearest the hydrogen sulphide apparatus.

Oxides into chlorides.—3. In the same manner as in experiment 2, conduct over heated ferric oxide, and cupric oxide, a current of hydrochloric acid gas.

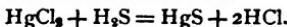
4. Treat another like portion of each oxide with 2 c.c. of **HCl** in a test tube.

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Sulphides into oxides.—5. Pass a stream of dry air or oxygen over 1 gm. of lead sulphide heated in an ignition tube; observe the odor of the gas that escapes from the tube and its action on blue litmus paper.



Chlorides into sulphides.—6. Pass a current of hydrogen sulphide through 3 c.c. of mercuric chloride.



7. Repeat the experiment, using a solution of cupric chloride instead of mercuric chloride.

Sulphides into chlorides.—8. Pour 2 c.c. of **HCl** over 1 gm. of lead sulphide, warm the mixture, then add 4 c.c. of water and boil; finally, allow the solution to cool.



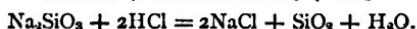
9. Mix together 0.5 gm. of silver sulphide and 1 gm. of sodium chloride and heat the mixture in a matrass; when the matrass has cooled, transfer its contents to a test tube, heat with 5 c.c. of water and test the solubility of the residue with **HNO₃**, and also with ammonium hydrate.



C. Properties of the oxides.—The oxides constitute the most important class of binary compounds, including the most common acids and bases, and many neutral bodies, or bodies exhibiting no chemical activity.

While all oxides whose solutions affect litmus have more or less energetic acid or basic properties, those of opposite character combining together to form salts, an oxide that does not change litmus at all may yet not be a neutral body.

1. Collect a few drops of hydrogen oxide by letting a jet of hydrogen burn within a clean and dry six ounce bottle for a few minutes, and test the product with litmus paper.
2. Burn a granule of sulphur in the deflagrating spoon in a wide-mouthed bottle, remove the spoon, add 10 c.c. of water, close the mouth of the bottle with the hand and shake it; then test with litmus.
3. Put a granule of phosphorus on a flat cork floated on a little water in the bottom of a six ounce bottle, and set fire to the phosphorus by touching it with the end of a heated wire; when oxidation has entirely ceased, close the bottle, shake up its contents, and test the water with litmus.
4. Perform a similar experiment with sodium, simply dropping the granule into the water in the bottle.
5. Hold a piece of thin copper foil in the upper part of the lamp flame, till it becomes covered with a coating of black oxide, put it into a test tube, shake it up with 5 c.c. of water, and test with litmus.
6. Repeat the experiment, using thin iron wire or foil instead of copper.
7. Put a granule of magnesium oxide on a slip of moistened red litmus paper; then treat a larger portion of the oxide with HNO_3 , and look for evidences of chemical action.
8. Put a little clean sand on a slip of moistened blue litmus paper; then fuse 0.5 gm. of finely pulverized sand on the platinum foil with 1 gm. of sodium carbonate; when the fused mass is cold, dissolve it in 10 c.c. of hot water, and, finally, add HCl as long as there is any effervescence.

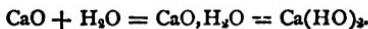


D. Hydrates.—Water plays an important part in chemical action in virtue of the very wide range of its solvent power. Of hardly less importance is its action in the formation of *hydrates*, in which the

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elements of water are retained in chemical combination, and the production of which is usually attended with evidences of chemical action.

1. Pour water over a small piece of burned lime.

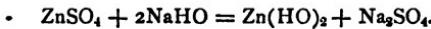


2. Cautiously burn a large granule of sodium in the deflagrating spoon, starting the combustion by holding the spoon for a moment in the lamp flame; let the product cool, and then plunge it into 1 c.c. of water in a test tube, the lower end of which is held between the thumb and finger.



3. To 1 c.c. of H_2SO_4 add 1 c.c. of water, slowly and with constant agitation, and from time to time touch the lower end of the tube with the hand.

4. Add 2 c.c. of sodium hydrate to 4 c.c. of zinc sulphate.



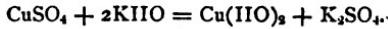
5. Add 5 c.c. of ammonium hydrate to 5 c.c. of aluminum sulphate, or of alum.



E. Basic substances combining with one another.

—Still further, substances that are strongly basic, i.e., which exhibit a strong tendency to unite with acids and form salts, may unite with one another.

1. To 5 c.c. of cupric sulphate add potassium hydrate solution in slight excess, or till the mixture, after agitation, quickly turns red litmus blue.



Collect the precipitate on a filter, and, when all the liquid has passed through, with a spatula transfer half of the precipitate to one evaporator and half to another, over one portion pour HCl, and over the other ammonium hydrate, and compare the results obtained.

F. The most important ternary compounds.—Considered either with respect to the abundance of their occurrence in nature or of their usefulness in the arts, the carbonates, nitrates, phosphates, silicates and sulphates of the metals are the most important *ternary* compounds.

1. Compare together in the manner described in A, sodium carbonate, nitrate, phosphate, and sulphate, taking 0.5 gm. for each test.
2. Compare in the same way calcium carbonate, nitrate, phosphate, sulphate, and silicate.
3. Compare zinc carbonate, nitrate, phosphate, sulphate, and silicate.

CHAPTR XVI.

Berthollet's laws.—Evolution of gaseous products.—

Formation of insoluble products.—Basic salts.—

Other products of the reaction when a gas is evolved.—Other products of the reaction when an insoluble product is formed.—Re-solution of the substance precipitated, by excess of the precipitant.

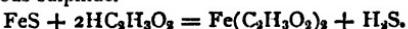
Berthollet's laws.—The nature of the reaction that will take place between two substances may often be predicted by reference to what are usually known as Berthollet's laws.

A. Evolution of gaseous products.—Whenever substances are brought together under conditions such that a new substance can be formed which is gaseous at the temperature of the experiment, this gas will be set free.

1. Pour H_2SO_4 over ferrous sulphide, and test for gaseous products by odor and with moistened test paper.



2. Pour acetic acid, one of the weakest of the acids, over powdered ferrous sulphide.



3. a. Compare the action of HCl and of boric acid in solution; separately, both on blue litmus paper and turmeric paper; then to a hot solution of 1 gm. of borax in 10 c.c. of water add **HCl**, drop by drop, with constant stirring, and occasionally test the solution with the two test papers, noting the color of the papers after drying them; add in all about 3 c.c. of acid.

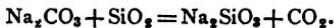


- b. Mix 1 gm. of boric acid with 1 gm. of sodium chloride, fuse the mixture in a porcelain crucible, and when the mass is well fused, remove the lamp for a moment while the end of a glass rod carrying a small slip of blue litmus paper, and one of turmeric paper, is held directly over the mouth of the crucible.

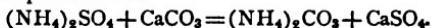
- c. Finally, heat 1 gm. of boric acid and 1 gm. of sodium chloride, separately, on platinum foil, and repeat the tests with test papers.

4. Rub together, in a mortar, 1 gm. of ammonium chloride and 1 gm. of lime, and apply various tests to determine whether either of Berthollet's laws is illustrated by the results.

5. Fuse 1 gm. of a mixture of equal parts of sodium carbonate and potassium carbonate in a crucible, and, when the fusion is complete, drop in a few grains of fine sand and continue heating for several minutes, and test the gaseous products and the solubility of the residue.



6. Mix intimately 1 gm. of calcium carbonate and 1 gm. of ammonium sulphate, and test for gaseous products by odor and moistened test papers; then heat the mixture gently in a dry test tube and repeat the test.



B. Formation of insoluble products.—When, in a mixture of solutions of different substances it is pos-

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sible by any chemical decomposition or rearrangement of the elements to produce a substance insoluble in the liquids present, that substance will be formed.

1. To 3 c.c. of calcium sulphate add 3 c.c. of ammonium carbonate; compare this result with that obtained in the preceding experiment.



2. To 3 c.c. of barium chloride add 1 c.c. of sodium phosphate.



3. Repeat the experiment, first adding 1 c.c. of HCl to the BaCl_2 , and then adding Na_3HPO_4 .

4. To 3 c.c. of BaCl_2 add 1 c.c. of calcium sulphate.



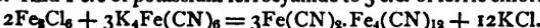
5. Repeat the experiment first adding 1 c.c. of HCl, as before, to the BaCl_2 , and then adding CaSO_4 .

6. To 1 c.c. of silver nitrate add 1 c.c. of sodium chloride; then add 2 c.c. of ammonium hydrate.



7. Repeat the experiment first adding 2 c.c. of ammonium hydrate to the AgNO_3 and shaking the mixture before adding the NaCl .

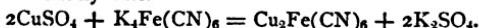
8. Add 1 c.c. of potassium ferrocyanide to 3 c.c. of ferric chloride.



9. Add 1 c.c. of ammonium hydrate to 2 c.c. of cupric sulphate; then add 2 c.c. of HCl.

10. Repeat the experiment first adding 2 c.c. of HCl to the cupric sulphate, and then ammonium hydrate.

11. Repeat the experiment using potassium ferrocyanide instead of ammonium hydrate.



12. Add 1 c.c. of potassium sulphocyanate to a few drops of ferric chloride, and then add silver nitrate, drop by drop, till a change occurs; finally add 1 c.c. of potassium sulphocyanate.

13. Pass a current of carbon dioxide through 5 c.c. of sodium silicate.

C. Basic salts.—The action of water in large quantities on solutions of salts of certain metals effects their partial decomposition, and the separation of a precipitate. This precipitate is generally a basic salt of the metal, i. e., a salt having a smaller proportion of acid than the original salt ; or it may, in rare cases, be a hydrate of the metal.

1. Dissolve a granule of bismuth in 3 c.c. of **HNO₃** with the aid of heat, add two drops of **HCl**, and pour a few drops of the mixture into a large test tube filled with clear water.

2. Dissolve a granule of gray antimony sulphide in 2 c.c. of **HCl**, boil the solution for a moment, and then pour a drop or two of it into clear water as in the preceding test.

3. Dissolve a small globule of mercury in a mixture of 4 c.c. of **HNO₃** and 2 c.c. of water, and boil the solution almost to dryness in an evaporator to expel excess of acid ; finally, pour one drop of the solution into a large test tube filled with clear water.

4. Boil a granule of tin with 2 c.c. of **HNO₃**, decant the liquid from the solid product, wash the latter once with water by decantation, heat the residue with 1 c.c. of **HCl**, add 5 c.c. of water and heat gently ; finally, pour 3 drops of the solution into 15 c.c. of clear water and heat to boiling for one minute.

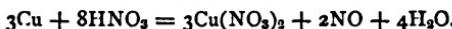
D. Other products of the reaction when a gas is liberated.—When a gas is liberated from a mixture of substances, in accordance with the law of Berthollet, other products of the reaction may be found in the residue.

1. Put a granule of sodium into a dish of water, and when the action has ceased drop in a piece of red litmus paper.

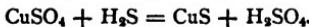


E. Other products of the reaction when an insoluble product is formed.—When a solid substance separates from a solution, in accordance with the law of Berthollet, the soluble products of the reaction may be found in the solution in which the precipitation was made.

1. Add silver nitrate drop by drop to 1 c.c. of HCl, shaking the liquid strongly after each addition, till no further effect is produced by a drop of the silver salt. Then decant the clear liquid, and heat it to boiling with a strip of copper foil.



2. Pass a current of hydrogen sulphide through 3 c.c. of cupric sulphate as long as a precipitate is produced; then, after letting the precipitate settle, decant the clear liquid into an evaporator and evaporate it slowly, almost to dryness, with a few scraps of filter paper. Finally, put a drop of H_2SO_4 on filter paper.



3. Pass a current of hydrogen sulphide through 3 c.c. of mercuric chloride as long as a precipitate is produced; after letting the precipitate settle, decant the clear liquid, heat it to boiling and test the vapor evolved with moistened blue litmus paper, and by holding the stopper of the ammonia bottle near the mouth of the tube.

F. Re-solution of the substance precipitated, by excess of precipitant.—When a solid is separated from a solution in accordance with the second law of Berthollet, it may in many cases be made to disappear on the addition of a further quantity of the substance by which it was precipitated.

1. Add 2 c.c. of potassium iodide, gradually, to 1 c.c. of mercuric chloride; then repeat the experiment reversing the proportions of each.
2. Add 5 c.c. of sodium hydrate, gradually, to 1 c.c. of alum.

CHAPTER XVII.

Modes of decomposition of salts and other compounds.—By heat.—By the galvanic current.—By an acid hydrate.—Partition of base between two acids.—Decomposition by a basic hydrate.—By another salt.—Dissociation.

The bromides, chlorides, cyanides, iodides, carbonates, sulphates, phosphates, nitrates, silicates, etc. of the metallic elements, as well as of ammonium, are designated by the general name of *salts*.

There are five principal methods by which salts may be decomposed, as follows:

- a. By heat alone.
- b. By the galvanic current.
- c. By the action of an acid or an acid hydrate.
- d. By the action of a basic hydrate.
- e. By the action of another salt.

A. Decomposition by heat.—

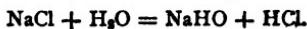
1. Put 3 gms. of cupric sulphate in a porcelain crucible, and heat the salt, at first gently and afterwards more strongly; soon after beginning to heat strongly, remove the lamp for a moment, while a thick folded piece of moistened blue litmus paper is held in the mouth of the crucible, but not in contact with the salt; then renew the strong heat and continue it for fifteen minutes; finally, when the residue is cold, throw it into a test tube of distilled water.

2. Perform a similar experiment with lead nitrate.

B. Decomposition of salts by the galvanic current.—

1. Put 5 c.c. of sodium sulphate at the bottom of a V tube, color the liquid with 2 c.c. of infusion of red cabbage, and carry down to the angle of the V tube the platinum plates connected with the poles of a four-cell Bunsen battery, in such a manner that the plates will be very near together, but not in contact, on the two sides of the angle.

2. Perform a similar experiment with sodium chloride, and explain the connection between the final result and the following equation, by resolving it into two equations expressing the two successive steps in the process of decomposition.

*C. Decomposition of salts by an acid hydrate.—*
When an acid is added to a solution of a salt, it is supposed that the basic radical is divided between the two acids, the one with which it was before combined and the one added, as illustrated by the following possible equation.

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While this may not be directly susceptible of proof, some experiments indicate such a partition.

1. Dissolve 1 gm. of cupric oxide in HCl, and observe the color of the solution; then add a few drops of HCl to 3 t.c. of cupric sulphate.

D. Result of this partition when one of the products is insoluble.—In a solution of such a mixture of salts and free acid hydrates as would be formed by the reaction indicated in the equation just given, we may suppose that there is a condition of equilibrium with respect to the relative proportions of the several acid hydrates and salts; this condition would depend upon the relative proportion of acid in the original combination, and of the free acid added, and on the relative attraction of the basic radical for the two acids respectively. Such a condition of equilibrium being established, if we suppose all of the potassium sulphate formed in the first instance to be withdrawn from solution, the equilibrium will be disturbed, and in order to reestablish it a fresh portion of the potassium nitrate will be attacked by the H_2SO_4 remaining free, a new state of equilibrium will be established different from the first, holding the same substances in

solution, but in different proportions. If the new portion of potassium sulphate can be removed the reaction will be repeated, and so on. Aided by this illustration, explain the results obtained in performing the following experiments :

1. To 1 c.c. of lead nitrate add 1-2 c.c. of H_2SO_4 in small portions of 8-10 drops each, shaking the mixture and letting it stand a minute after each addition.
2. Perform a similar experiment with HNO_3 and 0.5 gm. of sodium carbonate.
3. Perform a similar experiment with HCl and 0.5 c.c. of silver nitrate.

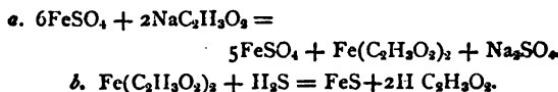
E. Decomposition of salts by a basic hydrate.—

1. To 1 c.c. of ferric chloride add 1 c.c. of sodium hydrate.
 $Fe_2Cl_6 + 6NaOH = Fe_2(OH)_6 + 6NaCl.$
2. To 1 c.c. of zinc sulphate add 1 c.c. of ammonium hydrate.

*F. Decomposition of salts by the action of another salt.—*A similar course of reasoning may be applied to the mutual action of one salt on another.

1. To 1 c.c. of barium nitrate add 1 c.c. of ammonium sulphate.
2. To 1 c.c. of silver nitrate add 1 c.c. of sodium chloride.
3. To 1 c.c. of calcium chloride add 1 c.c. of ferrous sulphate.
4. To 1 c.c. of silver nitrate add 1 c.c. of sodium phosphate.
 $3AgNO_3 + Na_2HPO_4 = Ag_3PO_4 + 2NaNO_3 + HNO_3.$
5. Conduct hydrogen sulphide through 5 c.c. of ferrous sulphate and also through 5 c.c. of ferrous acetate; then to 5 c.c. of ferrous sulphate add several drops of sodium acetate and pass hydrogen sulphide through the mixture. All these solutions must be quite neutral.

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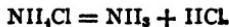


G. Dissociation.—The term *dissociation* is applied to a decomposition of chemical compounds produced, in many cases, by heat alone, but dependent to a large extent on changes of pressure and sometimes possible at common temperatures under variations in the composition of the surrounding atmosphere. On the restoration of the normal conditions, those under which the compound is permanent, the dissociated constituents may recombine.

1. Heat 1 gm. of mercuric oxide in a clean, dry test tube, and hold a glowing match at the mouth of the tube; finally, observe the deposit on the walls of the tube.
2. Put a granule of chalk or marble on a slip of moistened red litmus paper; then heat the granule for a moment in the lamp flame and again put it on the litmus paper.



3. Dissolve 1 gm. of ammonium chloride in 5 gms. of distilled water, and test the solution with red and with blue litmus paper; if it proves to be entirely neutral, heat 2 gms. of the same salt in a large, dry test tube till the tube is filled with its vapor; then hold a piece of blue litmus paper on a moistened glass rod first at the mouth of the tube, afterwards about half way within it, with care not to touch the sides of the tube. Finally, allow the tube to become perfectly cool, dissolve the residue remaining in it in 5 c.c. of cold water, and drop in a piece of blue litmus paper.



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4. Heat 2 gms. of hydrogen sodium carbonate (bicarbonate) in a dry test tube, and, by means of the adapter and exit tube, conduct the gas evolved into a test tube containing 4 c.c. of calcium hydrate.



5. Test 5 c.c. of ammonium chloride with red, and also with blue litmus paper; if it is perfectly neutral, heat the solution to boiling and observe the behavior of the litmus paper.

6. Heat 2 gms. of ammonium chloride in a large dry test tube and when the tube is full of its vapor introduce one drop of ferric chloride on a glass rod.

7. Repeat experiment 6, using cupric sulphate instead of ferric chloride.

CHAPTER XVIII.

Absorption of gases by porous solids.—Union of gases favored by condensation.—Concurring attraction.—Removal of substances from solution by porous solids.—Purification of water by filtration.

A. Action of porous solids on liquids.—When liquids or gases are brought in contact with porous solids, such as charcoal, clay, platinum sponge, fine powders, etc., they are absorbed and condensed in the pores of the latter and retained with more or less tenacity. This is regarded as a physical rather than a chemical phenomenon, resulting from the adhesive forces which come into play wherever the liquid or gas comes in contact with the surface of the solid; the greater the extent of this contact the more abundant will be the manifestation of such action. When the liquid or gas penetrates the solid,

moving freely through a multitude of fine tubes, or in narrow spaces between the particles of a fine powder, it is most readily affected in this way.

This absorbent power varies for the same solid and different liquids or gases, and for different solids and the same liquid or gas.

1. Cut out some pieces of well-burned charcoal, free from fissures, about .2 cm. in length and of such a diameter that they will readily slide into large test tubes. Fill a large test tube completely with ammonia gas by upward displacement, generating the gas in the usual way. Thrust into the tube a piece of the charcoal described above, having previously ignited it in a well-covered crucible and allowed it to cool, quickly close the tube with the thumb, immerse its mouth in the mercury of the mercurial trough, remove the thumb and allow the tube to rest for ten minutes on the shelf of the trough.

2. Repeat the experiment, using a fresh piece of charcoal, and sulphurous oxide, collected by downward displacement, instead of ammonia.*

3. Repeat again, using carbon dioxide, also collected by downward displacement, instead of sulphurous oxide, and allow the tube to stand for half an hour, carefully observing the height of the mercury in the tube before and after the experiment.

4. Repeat the experiment with ammonia gas, using platinized asbestos enclosed in a coil on the end of the platinum wire, instead of charcoal, and allow the tube to stand half an hour.

B. Union of gases favored by condensation.—
The diminution of the elasticity of the gases, resulting from this absorption and condensation,

* In these experiments the tube may be held in the test tube holder attached to the iron stand, one of the spirals enclosing the tube the other pressing upon its bottom.

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seems to facilitate chemical combination between them.

1. By means of a Y tube, connect an ignition tube containing a plug of ordinary asbestos with a reservoir of air, and a test tube in which ammonia gas is being slowly generated in the usual way, force out a slow stream of air from the reservoir, heat the asbestos while the mixed gases are passing over it, and test the products at the free end of the tube by means of red and blue litmus paper attached to a moistened glass rod.

2. Repeat the experiment, replacing the asbestos with a plug of *platinized* asbestos.

3. Repeat both experiments with common and platinized asbestos in turn, using, instead of air, hydrogen from the generator, with a safety tube attached, and a test tube in which nitric oxide is generated by the action of HNO_3 on copper, instead of the ammonia apparatus.

C. Concurring attraction.—Other reactions, similar to the foregoing in so far as the substance exerting chemical action appears to remain unchanged, do not admit of a similar explanation. The following experiments seem to show that, if to a compound containing an element in part loosely combined we add a substance having under the given conditions a weak attraction for this element, the latter, under the influence of this weak attraction, will escape from its combination, but will not unite with the body that induced its liberation.

1. Mix 1 gm. portions of potassium chlorate respectively with 0.5 gm. of each of the following substances: viz., man-

ganese dioxide, ferric oxide, lead oxide, zinc oxide and powdered glass; put these several mixtures into as many test tubes, and in another test tube put 1 gm. of potassium chlorate alone. Imbed the tubes side by side in sand to about the same depth as they are filled within, apply a gradually increasing heat, and, by means of glowing splinters frequently plunged into the different tubes, observe any difference in the readiness with which oxygen is evolved from the several mixtures. The three oxides first mentioned are capable of forming higher oxides.

2. Dissolve 1 gm. of oxalic acid in 5 c.c. of HNO_3 , heat almost to boiling, and, by means of the adapter and exit tube, pass any gas that may be evolved through calcium hydrate. Then add 1 c.c. of manganese sulphate to the oxalic acid, heat gently, and again observe the effect upon the calcium hydrate.

D. Removal of substances from solution by porous solids.—Porous solids will not only absorb and retain liquids within their pores, but will even withdraw substances from solution in these liquids; vegetable coloring matters and bitter principles are especially liable to this kind of absorption.

1. Grind 3 gms. of charcoal to a fine powder and ignite it strongly in a well covered crucible; fill a small filter with the powder when it has become cold, and pour over it 10 c.c. of dilute litmus (or cochineal) solution; compare the filtrate with the original solution.
2. Through a portion of animal charcoal ignited and put upon a filter in the same way, pass 10 c.c. of a weak solution of quinine sulphate and compare the taste of the filtrate with that of the original solution. Pour alcohol over the charcoal and repeat the test by tasting.
3. Filter a weak extract of logwood through precipitated lead sulphide on a filter.
4. Repeat the experiment, using freshly ignited charcoal instead of lead sulphide.

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E. Purification of water.—

1. Cautiously heat the bottom of a large, dry test tube in the lamp flame, then with a pointed flame heat a small spot to redness and, applying the mouth to the mouth of the tube, blow out the heated spot; fuse down the edges of the small orifice thus made, fill it with a tuft of cotton, over the cotton put a layer of clean sand 1 cm. thick, over this put a layer of freshly ignited charcoal powder 4 cm. thick, and over this again a layer of sand 1 cm. in thickness. Pour into the charcoal and sand filter thus formed some foul water, and compare what filters through with the original unfiltered water.

CHAPTER XIX.

Preparation of lakes.—Dyeing.—Washing a precipitate.

A. Preparation of the so-called lakes.—An excellent illustration as well as an important application of this surface attraction, between the particles of a solid and a substance in solution, is found in the preparation of *lakes*.

1. To 5 c.c. of alum add 4 c.c. of ammonium hydrate, heat the mixture, throw the precipitate on a filter, wash two or three times with hot water, and, with a spatula, transfer half of the precipitated aluminum hydrate to an evaporator. Prepare some extract of Brazil wood by digesting (moderately heating) 2 gms. of the chips with 25 c.c. of water for half an hour; add 5 c.c. of this extract to the precipitate in the evaporator, reserving the rest, stir vigorously and filter. Attempt to wash the color out of this precipitate by repeatedly pouring pure water over the filter containing it.

2. Perform a similar experiment with the extract of logwood made as in the case of Brazil wood, using the portion of aluminum hydrate remaining from the preceding experiment.

3. Add sodium hydrate, slowly and with constant stirring, to

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5 c.c. of stannous chloride as long as a precipitate continues to form, with care not to add an excess. Treat the precipitate as directed in the experiments with aluminum hydrate, and perform similar experiments with Brazil wood and logwood.

B. Dyeing.—In the art of dyeing advantage is taken of the strong attraction exhibited by these and other substances for vegetable and animal fibre on the one hand, and for the coloring matter on the other. Substances possessing this common attraction for the two classes of substances are called *mordants*.

1. Digest a piece of old linen or cotton cloth with extract of logwood and then wash it repeatedly with warm water. Prepare a solution of aluminum acetate by adding a solution of 6 gms. of lead acetate in 20 c.c. of water to a solution of alum of the same strength and filtering out the precipitated lead sulphate; test the effect of heat on a small portion of this solution.

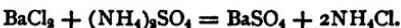
Soak a piece of old cotton cloth in a portion of this solution for twenty minutes, then in boiling water for five minutes, and wash well in distilled water; finally, soak half of the cloth thus prepared in extract of logwood, the other half in extract of Brazil wood for half an hour. Attempt to wash out the color from this dyed cloth.

2. Digest 5 gms. of fine iron wire or small tacks with 10 c.c. of strong acetic acid for four hours, decant the clear solution into an evaporator, soak a piece of clean cotton cloth in it, and expose the cloth to the air for two days; then wash the cloth in distilled water with a little soap, rinse in pure water, soak for half an hour in extract of logwood or Brazil wood, and, after drying, test the permanence of the color by washing as before.

C. Washing a precipitate.—When a substance has been precipitated from a solution and collected on a

filter, the filter and its contents are necessarily saturated with the liquid in which the precipitate was made, and with the matters dissolved in that liquid. The important operation of washing the precipitate consists in repeated treatment with water till all the impurities are carried away—a process much more difficult with some precipitates than with others.

1. To 10 c.c. of a boiling solution of barium chloride add 10 c.c. of boiling ammonium sulphate.



Allow the mixture to stand ten minutes, collect the precipitate on a small filter, and when the last portions of the liquid have passed through, wash the precipitate by repeatedly filling the filter with water heated to boiling in a test tube, allowing each portion to pass through completely before adding another. After repeating this treatment five or six times put a drop of the washings on a slip of glass or platinum, carefully evaporate it to dryness, and, after observing the residue, receive another drop of the washings in a test tube containing 2 c.c. of HNO_3 and a drop of silver nitrate. Explain the meaning of these tests.

2. Repeat the experiment using ferric chloride instead of barium chloride and ammonium hydrate instead of ammonium sulphate, and compare the quantity of water required for complete washing of this precipitate with that required in the previous experiment.
3. Repeat both experiments using cold instead of hot water.
4. Prepare two filters, one ribbed and one common, placed in separate funnels, fill each with a dilute solution of potassium dichromate, and compare the quantities of water required to wash the color out of each.

CHAPTER XX.

*Inorganic and organic matter compared.—Dialysis.
—Crystalloids and Colloids.*

A. Mineral, Vegetable and Animal Substances compared.—With the exception of oxygen and nitrogen, which exist at and above the surface of the earth in vast quantities in the free state, the chemical elements are almost entirely combined together, forming mineral, vegetable and animal matter.

i. Compare together these three forms of matter, taking any piece of rock or stony material, some fresh twigs of a tree or shrub, and a piece of fresh, clean meat as types of the three classes of matter.

a. Put a small portion of each in a clean, dry test tube and apply heat not exceeding 100° C. This is most conveniently done by partly immersing the test tube in an evaporator containing boiling water.

b. Heat 0.5 gm. of each in a large matrass, gently for a time, afterwards quite strongly; test the gaseous products, from time to time, with red and blue litmus paper.

c. Heat 1 gm. of each on platinum foil, gently at first, afterwards to the highest temperature attainable with the lamp, till no further change is apparent.

d. Put 2 gms. of each in a test tube, add 3 c.c. of water, and set aside in a warm place for two or three days, noting any phenomena that may appear, and testing frequently with litmus paper.

e. Study the action of water, strong basic hydrates, such as potassium or sodium hydrates, and of strong acids on each, with and without the aid of heat. For these tests the substances should be finely divided by breaking or cutting.

B. Dialysis.—*Crystalloids and Colloids.*—A certain class of uncrystallizable substances called colloids, of which the albumen in solution in white of egg, and the caseine in solution in milk are good examples, will not pass at all through parchment paper, or thin animal membranes, while any crystallizable salts, like sodium chloride or potassium sulphate, pass readily through such a septum under certain conditions. These colloid substances are much more common in the organic than in the inorganic world. A mode of separating substances, based upon this principle, and often used in chemical processes, is called *dialysis*.

1. To make a dialyser first heat the bottom of a large, wide test tube to redness, burst it out by forcible blowing at the mouth of the tube, and fuse down the ragged edges of the orifice by heating for a moment in the lamp flame; cut out a disk of bladder an inch larger than the diameter of the tube, soften it by soaking in water, and bind it with a strong thin cord over the mouth of the tube. Add 1 c.c. of sodium chloride to 5 c.c. of white of egg and 10 c.c. of water, mix the whole well together and pour it into the dialyser; then press together the sides of a wire triangle so

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that the dialyser, protected by a ring of folded paper, passes through it with some friction, suspend it, mouth downwards, in a tumbler containing distilled water so that the water will stand at the same level within and without the tube, and leave it in this position for twelve hours. Then add a few drops of the outer liquid to 1 c.c. of HNO_3 containing a few drops of silver nitrate, and heat another portion of 10 c.c. to boiling in a test tube; finally, add 5 c.c. of the liquid within the dialyser to 5 c.c. of water and heat to boiling; albumen is precipitated.

2. Perform a similar experiment with 15 c.c. of milk to which 1 c.c. of potassium sulphate has been added, and, instead of testing for chlorine in the outer liquid, test for H_2SO_4 by adding 1 c.c. of HCl and a few drops of barium chloride; and to test for caseine, the most important colloid substance in milk, heat a few drops of the same outer liquid with three drops of acetic acid; finally, to compare the inner with the outer liquid, mix 5 c.c. of the former with 5 c.c. of water, add a few drops of acetic acid and heat.

CHAPTER XXI.

Quantitative analysis of gaseous mixtures.—Law of definite proportions illustrated by quantitative methods.

A. Gas analysis.—The property possessed by some liquids of absorbing certain gases finds an important application in the quantitative analysis of gaseous mixtures; this is frequently performed in the laboratory by the use of liquids having special capacities for the absorption of certain gases. Each constituent of the mixture being removed in turn by a given liquid, the loss of volume at each successive stage indicates the volume of a certain gas originally present. Nitrogen gas, which is not readily absorbed by any liquid, is usually measured directly as a residue after all other gases have been removed.

The following experiments are designed to illus-

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trate the method of analysis without demanding the time or skill required in accurate analysis. The graduated tube used in all of the experiments is made from a long, narrow test tube in the bottom of which is fixed a disc of cork saturated with paraffine, which is of such a size as to fit snugly within the tube and furnish a flat bottom for it. A narrow slip of writing paper, as long as the tube, is graduated with the pen into half centimetres, and after fastening it lengthwise upon the tube from end to end, the divisions are numbered, beginning at the closed end of the tube, so that the first division shall be 0.5 cm. above the level of the bottom which is marked 0; the graduated paper scale is finally coated with common varnish to exclude the water. The quantity or bulk of gas corresponding to one division of the scale will be spoken of as a *volume*; its actual volume in cubic centimetres is of no importance for the present purpose.

1. Fill the graduated tube with water, insert it in the water of the pneumatic trough, and introduce 15 volumes of pure carbon dioxide from a generator; close the tube with the thumb protected by a rubber finger-cap, plunge its mouth below the surface of the liquid in an evaporator containing 50 c.c. of sodium hydrate and secure it with a leaden ring; remove the tube after three minutes, closing the mouth as before to prevent any escape of the gas, and shake it strongly so that the small quantity of liquid which has entered may wet the walls of the tube, replace it in the evaporator, and after ten minutes note any change in the volume of the gas.

2. Repeat experiment 1, using 15 volumes of atmospheric air in the tube instead of carbon dioxide, and putting into the evaporator an alkaline solution of pyrogallic acid instead of sodium hydrate.

3. Repeat experiment 2, adding 5 volumes of carbon dioxide to the 15 volumes of air before treating it with the absorbing liquid.

4. Bend a thin wire, 30 cm. long, upon itself so that one limb shall be one third of the length of the other, but parallel with it and about 2 cm. distant from it; attach to the wire a disk 1 cm. in diameter cut from the end of a cork, and on this lay a granule of well-dried phosphorus; sink the curved part of the wire into a vessel of water till the cork is within 3 cm. of the surface, then ignite the granule by the touch of a hot wire, and quickly invert over it a large test tube filled with atmospheric air, putting the mouth of the tube at least 1 cm. below the surface of the water. Hold the tube in this position till the air within is perfectly clear, then withdraw the wire and cork, keeping the tube still immersed; close the tube with the thumb, withdraw it and carefully measure the water it contains by pouring it into the graduated tube. Finally, fill the test tube with water, find the volume of its contents by means of the graduated tube, compare this volume with that of the water first measured, and explain the meaning of the result.

5. Fasten a well-dried granule of phosphorus on the point of a thin wire, introduce this into the graduated tube so that it may reach the middle, invert the tube, while filled with atmospheric air, over water, secure it with a leaden ring, and after it has stood for two or three days, note any change in the volume of the air within the tube. Finally, test the residual gas with a lighted match.

B. Law of definite proportions illustrated by quantitative methods.—The law of definite propor-

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tions is one of the most important fundamental laws of chemistry. It expresses the well established principle that elements and compounds, when they unite chemically with one another, combine in fixed and definite proportions. The same weight of potassium, when converted into chloride by contact with chlorine, will always yield the same weight of potassium chloride, provided there is in every case present and accessible to combination at least 35.5 parts by weight of chlorine for 39.1 parts of potassium ; but whatever may be the quantity of chlorine present over and above what this proportion requires, no more potassium chloride will be formed. Or, when sodium carbonate is converted into sodium chloride by treatment with HCl, the same weight of the pure anhydrous carbonate will always yield the same weight of chloride, provided that in every case there are at least 73 parts by weight of HCl present and accessible to combination for every 106 parts of the carbonate ; but whatever may be the excess of HCl over and above what this proportion requires, no more sodium chloride will be formed.

It is now proposed to impress this law upon the mind of the student by a few examples, and at the same time to make him acquainted with some of the operations of quantitative analysis. The results cannot possess the accuracy of those which could

be obtained by the skilled chemist with trained hand and judgment, and delicate balance ; but, nevertheless, if the directions given in the articles on filtration, quantitative manipulation and weighing, Introduction, § 2, are carefully followed, the law under consideration may be well illustrated.

1. Get the tare* of a small beaker containing a short glass stirring rod, and weigh out in it, accurately, 5 gms. of pure, well dried sodium carbonate; then add 20 c.c. of pure water, and finally HCl, drop by drop, with constant stirring, waiting till the effervescence caused by one drop has nearly subsided before adding another. Continue this operation till further addition of the acid causes no more effervescence, and then put the beaker on the water bath and expel the water by evaporation, with constant stirring as the residue becomes dry; when the salt appears to be perfectly dry, with a dry cloth wipe the water off of the outside of the beaker, and then heat it gently on a moderately heated sand bath till no moisture is condensed on a cold watch glass laid over the mouth of the beaker. When the beaker is perfectly cold, weigh it again with the tare on the other pan. Then heat the beaker and its contents again on the sand bath for half an hour, and weigh once more when cold; if the weight is constant the desiccation is complete.

2. Repeat the experiment taking, however, 3 gms. of the carbonate, and HCl in small excess over the amount required for complete decomposition.

If w represents the weight of NaCl obtained in the first operation, then by the proportion

$$5 : 3 :: w : x,$$

the student can calculate from his first result how much chloride the 3 grammes of carbonate taken

* See "weighing" p. xxv.

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for the second trial should yield, if his work is carefully performed, and the law of definite proportions holds good in this case.

On writing out the equation for the reaction between sodium carbonate and HCl it will be seen that one molecule of the carbonate yields two molecules of sodium chloride. The relative weight of a molecule (molecular weight of a compound) is obtained by adding together the weights of the atoms composing it, each atomic weight being multiplied as many times as it is taken in the formula ; thus the molecular weight of sodium carbonate is calculated as follows :—

$$\text{Na}_2 = 23 \times 2 = 46$$

$$\text{C} = 12 \times 1 = 12$$

$$\text{O}_3 = 16 \times 3 = 48$$

$$\text{Total} = 106.$$

Similarly, the molecular weight of sodium chloride is found to be

$$\text{Na} = 23 \times 1 = 23$$

$$\text{Cl} = 35.5 \times 1 = 35.5$$

$$\text{Total} = 58.5.$$

$58.5 \times 2 = 117$ = relative weight of two molecules.

Then by the proportion

$$106 : 117 :: 5 : x.$$

the student may estimate the quantity of sodium chloride that the 5 grammes of sodium carbonate should yield, if the manipulation was carefully per-

formed, and the law of definite proportions is valid. The same calculation may be made for the other quantity of sodium carbonate.

3. Perform a similar set of experiments with sodium carbonate and HNO_3 instead of HCl, and make the corresponding calculations.

4. Perform similar experiments and calculations with barium carbonate and HCl.

5. Perform similar experiments and calculations with barium carbonate and HNO_3 .

6. Get the tare of a large porcelain crucible about 4 cm. deep containing a short stirring rod, weigh out in it 2 gms. of clean copper, take the crucible to the ventilating hood and pour moderately concentrated nitric acid (equal parts HNO_3 and water) over the copper, in portions of 3 c.c. at a time, quickly covering the crucible with a watch glass, convex side downwards, after each addition and waiting a few moments before adding the next portion; when enough acid has been added to dissolve all the copper, rinse off the cover into the crucible, evaporate the water over the water bath, and ignite the dry residue, moderately at first and for a considerable time, and afterwards strongly. Set the crucible in the desiccator to cool, and when it is cold weigh it. The residue is cupric oxide, CuO .

7. Repeat the experiment taking 3 gms. of copper instead of two, and adding a small excess of acid.

8. Get the tare of a large porcelain crucible about 3.3 cm. deep and weigh out in it 2 gms. of clean lead foil; set the crucible on the water bath in the ventilating hood, pour over the metal 9 c.c. of a mixture of equal parts of HNO_3 and water, and cover immediately with a watch glass, convex side downwards; when all the lead is dissolved, rinse the glass into the crucible, and evaporate off the water, as usual, on the water bath; when the residue appears to be quite dry, transfer the crucible to the drying bath, after an hour or two take it out, and weigh it when cool. Then heat again in the drying bath and weigh once more; if the weight is constant, the drying is completed. The residue is lead nitrate, $\text{Pb}(\text{NO}_3)_2$.

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9. Heat the crucible with the residue obtained in experiment 8, in the direct flame of the Bunsen burner, at first with its cover on and very gently; gradually raise the temperature, finally remove the cover and heat as strongly as possible; when cold, weigh. The residue is lead oxide, PbO .

10. Repeat experiments 8 and 9, taking 3 gms. of lead and 15 c.c. of the mixture of acid and water.

11. Weigh out one gm. of silver foil in a tared watch glass, pour 10 c.c. of moderately concentrated nitric acid over it in a small beaker, cover the beaker with a watch glass, and warm it in the sand bath; when all the metal is dissolved, rinse off the cover into the beaker, and add a clear solution of sodium chloride as long as any precipitate is formed and stir the mixture vigorously, with due care not to spatter any of it out of the beaker. Let the mixture stand in quiet till the precipitate has settled to the bottom, and then add a few more drops of sodium chloride, in order to be sure that all the silver is precipitated; if the reaction is found to be complete, collect the precipitate on a filter tared by another filter (see filtration, § 2, Introduction) and wash both filters with hot water till a drop of each filtrate, taken separately, causes no turbidity in 1 c.c. of HNO_3 containing three or four drops of silver nitrate; then cover both funnels with filter paper, put them in the drying bath, and when dry weigh; return both to the drying bath and after an hour weigh again; if the weight is constant the desiccation is complete. The product is silver chloride, AgCl .

12. Repeat the experiment using 2 gms. of silver instead of 1 gm. and a small excess of sodium chloride. Calculate the theoretical results in both ways, for the two trials.

13. Weigh out two gms. of clean lead foil or shavings in a tared watch glass, pour over the metal, in a small beaker, 30 c.c. of a mixture of 10 c.c. of HNO_3 and 50 c.c. of water, and cover the beaker with a watch glass; when the solution is complete, rinse down the walls of the beaker with the wash-bottle jet, and then conduct a slow stream of hydrogen sulphide through the solution as long as any precipitate appears to be formed; let the precipitate settle, pass a few more bubbles of gas through the clear supernatant liquid, to make sure that all the lead is thrown down, and then

proceed to collect the precipitate on a filter tared by another filter, wash both filters with water which has been saturated with hydrogen sulphide till a drop of the washings evaporated on a watch glass in the sand bath leaves no residue, and dry and weigh as directed in the case of silver chloride. The product is lead sulphide, PbS.

14. Repeat the experiment using 3 gms. of lead, and 40 c.c. of the diluted acid, and calculate the theoretical results in both ways, for the two trials.

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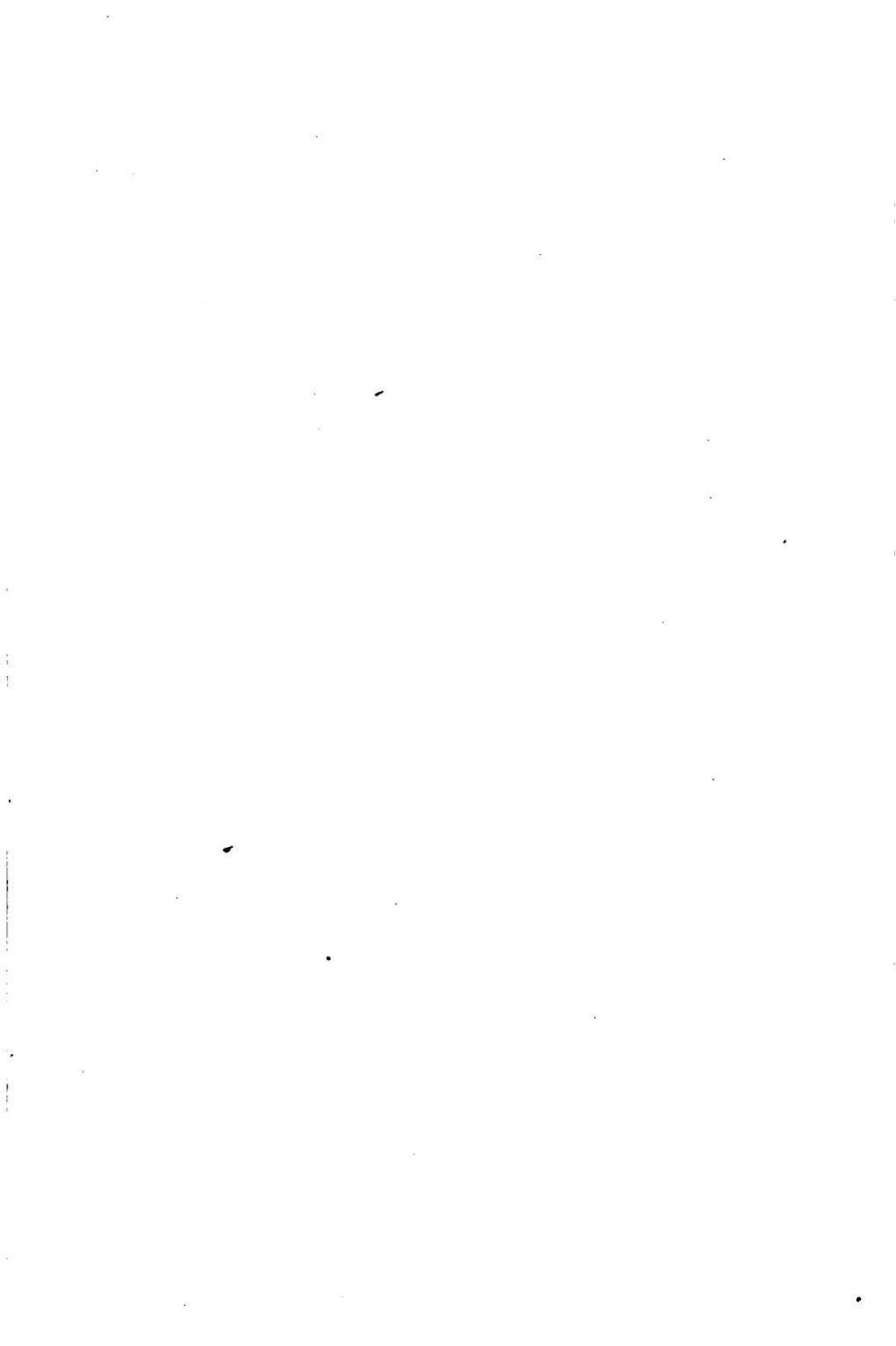
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